This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

A 757,543 DUPL

SYSTEMS OF

CAR LIGHTING.

Library
TF
147
K4

THE COMPARATIVE MERITS

OF VARIOUS

SYSTEMS OF CAR LIGHTING

AN INVESTIGATION OF THE COMPARATIVE COST, SAFETY,
LIGHT-GIVING POWERS AND GENERAL ADVANTAGES OF
OIL LAMPS, GASOLINE CARBURETERS,
COMPRESSED GAS, ELECTRIC LIGHTING.

BASED UPON ORIGINAL INVESTIGATIONS AND TESTS
MADE EXPRESSLY FOR THIS WORK, AND ON THE BEST
AVAILABLE STATISTICAL RECORDS.

rthur ellen

BY

A. M. WELLINGTON
Editor Engineering News

W. B. D. PENNIMAN
Chemist Baltimore & Ohio R. R.

AND

CHARLES WHITING BAKER
Associate Editor Engineering News

WITH 77 ILLUSTRATIONS AND COMPLETE INDEX

NEW YORK
ENGINEERING NEWS PUBLISHING CO.
1892

TY OF MICHIGAN
APR 15 1927

PREFACE.

It is literally a "burning question" at the present time what system of lighting is safest, cheapest, and on the whole best for use on passenger cars. It is a question, moreover, on which there is considerable difference of opinion, due in no small degree to the lack of accurate and impartial information as to the merits and demerits of the various systems, in respect to safety, first cost, operating cost, light-giving powers and general utility.

The present treatise, a revised reprint of a series of articles which has been appearing at intervals during a year past in Engineering News, is an attempt to aid an intelligent choice by recording impartially the results of a series of new and searching tests of the several systems. These tests were undertaken with the consent and co-operation of the proprietors, and covered a good deal of ground which had never been covered before, at least by any tests of record, or by any tests of which the authors have been able to obtain any trace. The records of these new tests are supplemented by complete descriptions of all the several plants, and by abstracts of all attainable records of their performance in service or in prior tests.

The authors have endeavored to avoid giving expression to any conclusions of their own, so far as clearness and completeness would permit; and in so far as they have expressed any conclusions, the facts on which they are based are all recorded in this volume to enable the reader to form his own independent conclusions.

Realizing that large business interests were liable to be seriously affected by an inquiry of this nature, and that it would be an injustice to such interests to record as facts anything not established by adequate evidence, or as opinions anything in regard to which there appeared to be reasonable doubt, the authors have taken every pains to insure accuracy and impartiality by sending advance proofs of all these articles, some days or weeks before their first publication, to all known parties in interest (as also to many other persons supposed to be competent critics), with request for criticisms or suggestions. All such criticisms have been duly weighed, and where possible adopted, or where impossible the opposing views presented by parties in interest have been simultaneously published.

As a further precaution against any injustice, the authors have extended to all parties in interest the privilege of appending a statement in their own words to this treatise, specifying the exceptions which they desired to take to any parts of the treatise, and the evidence on which they based their conclusions. The sole condition attached to this offer was that such criticisms should be of a specific nature and confined to technical points. Such criticisms as have been received in response to this offer are printed in connection with the matter criticised.

On the other hand, the authors have felt that they were bound to regard public as well as private interests, and that, having undertaken this investigation with the full consent and co-operation of all parties in interest, it was their duty to record all facts which made against any system, as well as for it.

TABLE OF CONTENTS.

Page.

The Nature of Illuminants Used in Car Lighting.. 3

Photometric Instruments Used and Manner of Testing of Frost Carbureter System.................. 12

The Frost Dry Carbureter Plant.................. 21

Extent of use, 24.—Details of, 26.—The carbureter, 32.—Functional action of, 35.—Tests of strength of carbureter, 43.—Central R. R. of Georgia, accident, 54.—Charging the carbureters. 58.—Miscellaneous notes on, 67.—Functional action of, 75.—Tests of temperature in carbureters, 80.—Air passages in carbureters. 86.—Test of hours service from one charging, 92.

The Pintsch Compressed Oil Gas System.......... 96

Gas making and storing plant, 97.—Cost of gas making, 102.—Danger in gas works, 108.—Storing and distributing the gas, 113.—The plant on the car, 119.—Extent of use, 126.

Oil-Burning lamps.................................. 132

Defects of vegetable oils, 132.—Mineral sperm oil, 133.—Pennsylvania R. R. specifications for oil, 136.—Baltimore & Ohio specifications for oil, 144.—Lamps, 147.—Tests of burners, 149.—Car lamps, 150.—Correspondence, 156.

Page.

Electric Lighting.................................. 160

Primary battery system, 162.—Track wire system, 164.—Storage battery system, 165.—Direct dynamo system, 168.—Combined storage battery and dynamo system, 170.—Electric train lighting in England, 171.—American practice in combined dynamo and storage battery system, 179.—Comparative cost of different electric systems, 180.

The Comparative Photometric Value of Oil, Gas, Gasoline, and Electric Lights.................. 194

Photometric standards used, 196.—Results of candle power tests, 200.—Comparison of lamps and systems tested, 206.—Candle power of electric lamps, 210.

The Comparative Cost of Car Lighting Plants...... 213

First cost and depreciation of oil lamps, 213.—First cost and depreciation of Pintsch gas system, 214.—First cost and depreciation of Frost carbureter system, 218.—Comparative cost of operating, 222.—Cost of illuminants, 229.—Total yearly cost, 234.

The Comparative Safety of Various Car Lighting Plants....................................... 240

Comparative safety of illuminants used, 243.—Comparative safety of Pintsch gas system, 245.—Comparative safety of oil lamps, 253.—Comparative safety of the Frost carbureter system, 265.—Accidents from gasoline, 273.—The effect of the functional action of the Frost carbureter system upon its safety, 275.

Appendix.—Car Lighting by Storage Batteries, Jura & Simplon Ry........................... 290

LIST OF TABLES.

Page
I. Properties of the various commercial distillates of crude petroleum............................ 7
II. Estimated present yearly output of the several petroleum products............................ 9
III. Detail record of the consumption of air and gasoline by a Frost carbureter................. 18
IV. Comparative summary of first and last hours of each burning.................................. 20
(V. omitted in numbering tables.)
VI. Endurance test of carbureters on Car No. 985, P. R. R.................................... 92
VII. Temperature (in degrees Fahr.) in and about the carbureter during a 7-hour test of the Frost carbureter light............................... 80
VIII. Test of the temperature in and about carbureters, and of the effect of shutting off air supply, through by-pass only and altogether............ 81
IX. Candle power of various car lights for each 10° of arc below the horizontal.................... 200
X. Value in visual units (one c. p. shown at a distance of 4.5 ft.) of the lights shown in Table IX. in a horizontal plane 4.5 ft. below light. Light assumed to strike a plane normal to the rays.... 203
XI. Visual units striking a book held at an angle of 45° by an occupant of each seat in the car with various lamps or chandeliers, placed 6 ft. and 9 ft. apart.................................... 206
XII. Summary of estimated average total cost of lighting a car one year, three hours per day.... 234

LIST OF ILLUSTRATIONS.

Fig. No. Page.

1. Diagram of certain physical properties of the various commercial distillates of crude petroleum. 6
2. Percentage of the vapor of gasoline retainable by air at various temperatures.................. 11
3. Dibdin's radial photometric apparatus.......... 12
4. Diagram illustrating radial photometer........ 14
5. Diagram illustrating radial photometer........ 15
6. Arrangement of Frost carbureter plant for test. 17

(Numbers 7 to 20, inclusive, were accidentally skipped in numbering the figures, through a change in the order of discussion of the different topics.)

21. General arrangement of the several parts of the Frost dry carbureter plant...................... 26
22. Check valves and dust screen................ 26
23. Air tank. P. R. R. standard.................... 27
24. Tank needle valve............................ 28
25. Bowman regulator and indicator.............. 29
26. Chapman regulator........................... 31
27 Mercurial safety valve....................... 26
28. Section of standard circular carbureter, P. R. R. 32
29. Plan of standard circular carbureter, P. R. R.. 32
30. Filling valve.................................. 35
31. Discharge valve.............................. 36
32. Joint between carbureter and lamp.......... 36
33. Star burner, of the regenerative Lungren type, the present standard lamp..................... 32
34. New carbureter cut open to show wicking and interior construction........................ 43

Fig. No. Page.
35. New carbureter cut open after being subjected to severe fire test............................ 45
36. View of new carbureter after having been subjected to fire test, and thereafter recharged and placed under a steam hammer..................... 47
37. Bottom view of same....................... 48
38. Drop test of carbureter....................... 52
39. Carbureter after testing..................... 53
40. Charging can................................ 59
41. Gasoline charging can house................. 60
42. Standard perforations for wicking, new square carbureter (full size)........................... 64
43. Excelsior lamp, Frost carbureter system, as formerly used on Pennsylvania R. R.......... 77
44. Present form of lamp, Frost carbureter system. 78
45, 46. Diagrams illustrating the functional action as respects temperature and air consumption of the Frost dry carbureter plant, as now manufactured by the company........................ 80
47. Position of thermometers during tests of Frost carbureter plant............................ 80
48. Sketch of general arrangement of experimental plant in the factory of the Railroad Lighting & Manufacturing Co., with which the records of Figs. 45 and 46 were determined............. 83
49. Passages for air through and around carbureter 86
50, 51, 52. Retorts used in Pintsch gas works, Glasgow, Scotland; supplying the Caledonian Ry. 98
53. Gas compressing engine at Boston gas works of the Safety Car Heating & Lighting Co........ 98
54. Arrangement of supply tank and pipes for feeding crude petroleum to gas retorts; Pintsch gas works of Central railroad of New Jersey, Jersey City.. 110

Fig. No. Page.
55. Diagram of changes of pressure in storeholders at gas works at Hainholz and in accumulator at Hanover while filling cars.................. 118
56. Pintsch compressed gas lighting plant attached to car.. 118
57. Car reservoir for compressed gas, Pintsch system.. 118
58. Detail of joint between shell and head of car reservoir 118
59. Section of Pintsch regulator.................. 118
60. Section of standard lamp of Safety Car Heating & Lighting Co.............................. 118
61. Perspective view of standard lamp............ 118
61½. Vertical section of Belgian lamp burner.... 154
62. Westlake's improved ventilating car lamp, with Belgian burner.............................. 154
63. Method of driving dynamo from car axle for train electric lighting, in use on London, Brighton & South Coast Ry., England................. 172
64. Method of driving dynamo from car axle in use on Midland Ry., England....................... 172
65. Candle power tests of oil lamp, Belgian burner, 2-lamp chandelier, 3.5 oz., oil per hour.......... 200
66, 67, 68, 69. Candle power tests of various forms of Pintsch oil gas burners; 6-flame burner, present and old form of 4-flame burner and Porter regenerative burner............................ 200
70, 71, 72. Candle power tests of various forms of burners used with Frost gasoline system of car lighting—inverted Lungren burner (present form), old Excelsior burner, and Dudley's P. R. R. burner.. 200
73. Diagram showing the visual units supplied by one lamp or chandelier of each kind tested.... 202

Fig. No. Page.
74. Position of visual plane and total visual units supplied by all the lights in a car to each seat therein, with lights 6 ft. apart.................. 206
75. Total visual units supplied by all of the lights in a car to each seat therein with lights 9 ft. apart.. 208
76. Candle power tests of incandescent electric lamps.. 210
77. Candle power tests of an electric arc light using various carbons............................ 210

THE
COMPARATIVE MERITS
OF VARIOUS SYSTEMS OF
CAR LIGHTING.

[REPUBLISHED FROM ENGINEERING NEWS, BEGINNING APRIL 18, 1891.]

As has been intimated in prior issues of ENGINEERING NEWS, we have been collecting for some months past the material for the following brief treatise on the comparative merits and demerits of the various systems of car lighting, of which there may be said to be only three of much present prominence for general use, viz.:

1. Oil lamps.
2. Compressed oil gas.
3. Air gas generated from gasoline.

Electric lighting is as yet too dear, and candles are both too dear and too poor an illuminant to enter largely into the immediate practical question. Compressed coal gas is used by only one company, and not approved by it. Nevertheless we give some details as to these also.

The primary question with regard to any and all systems of car lighting must be, How much effective light is obtained from it for a given quantity of combustible? This part of the investigation was undertaken by Mr. W. B. D. PENNIMAN, Chemist of the Baltimore & Ohio Railroad, known to us as an expert in such matters, who kindly arranged to give the very considerable time required for some careful photometric tests, as he could spare it from his other and regular duties.

These tests he has at last completed, after some unavoidable delay, and our readers will agree with us that they constitute the most complete evidence on this subject which has as yet appeared.

Mr. PENNIMAN has also given us the benefit of his counsel and assistance in collating and digesting the records generally, which his intimate practical knowledge of the subject has enabled him to do most effectively. For the correctness of the photometric and chemical tests, however, he is alone responsible, and for all the remaining facts and opinions this journal is responsible.

In the meantime, Mr. GEORGE GIBBS, Mechanical Engineer of the Chicago, Milwaukee & St. Paul Ry., has prepared and read a valuable paper on the subject of car lighting (republished in ENGINEERING NEWS for March 7-14, 1891), which in a measure covers the same ground as that which we have proposed to cover. In part it more than covers it, and in part falls short of doing so, as is but natural, and, as in some respects his results are discordant from those which we have reached, we shall include the data in his paper with the rest of our material, point out the points of agreement and difference, and thus, we hope, make both his records and our own more valuable. Some of the points of difference are of much importance.

The question of car-lighting methods naturally divides itself into these sub-heads:

1. The nature of the illuminant.
2. Comparative photometric efficiency.
3. The construction and cost of the plant.
4. The cost of operation, maintenance and renewal.
5. Comparative safety and convenience.

We shall consider the subject in this order.

THE NATURE OF THE ILLUMINANTS.

The illuminants used for all three of the chief systems of car illumination are products of the distillation of crude petroleum, the Pintsch and other oil gas systems,* making a permanent gas from crude petroleum or some of its products; the oil lamps using some one of the kerosene oils, which range from 110° to 150° Fahr. fire-test for the ordinary household oil to the "mineral sperm" or 300° fire-test oil, the last the only one ordinarily used, and the only one which the law of most states permits to be used for lighting passenger cars; and the carbureter system using a gas formed (*i. e.*, supposed to be formed) by passing air through gasoline and charging it with its vapor. As a matter of fact, however, this gas would seem from the records below to consist chiefly of the vapor or steam of gasoline heated above its boiling point (110° F.).

---

*There is at present no other system of oil-gas lighting before the public but the Pintsch, which is controlled by the Safety Car Heating & Lighting Co., of 160 Broadway, New York. There was formerly another, organized by Mr. J. M. Foster, and known as the American Lighting Co.; but this company is now out of business, so far as we are informed. It is claimed that their method of manufacturing gas was less perfect than the Pintsch, and some accidents to their gasworks on the Reading and other roads have been erroneously supposed to have been accidents to Pintsch works.

In order that the photometric tests may be properly interpreted, a few facts as to the nature of crude petroleum and its products may be given now better than later.

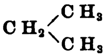
All crude petroleums are irregular mechanical mixtures of the following so-called paraffine series, the general formula for which is $C_n H_{2n+2}$, no one of which series is ever found in nature separate from the rest, nor can it be obtained from the mixture by ordinary processes of distillation:

		Boiling point.
Methane	$C H_4$ (Marsh gas)	Gas.
Ethane	$C_2 H_6$	"
Propane	$C_3 H_8$	"
Butane	$C_4 H_{10}$	1°
Pentane	$C_3 H_{12}$	38°
Hexane	$C_6 H_{14}$	70°
Heptane	$C_7 H_{16}$	984

and so on down to

$C_{24}H_{50}$ in paraffine.

The upper compounds of the series are gases, then highly volatile liquids, followed by liquids of greater weight and lower boiling point, and finally by solids. The series is even more complicated in practice than it appears above, as all the single compounds below $C_4 H_{10}$ (butane) have (or may have) one or more substances of the same formula but entirely different properties, boiling point, etc. The single compounds have been prepared in some cases, but the process is often slow and difficult. All the members of the series, however, are characterized by a remarkable chemical indifference, and are unaffected by mineral acids and alkalis which, in practice, are used to effect their separation from other substances. The complication of the series given above is much increased by the fact that there are other substances which belong to this series of the formula of $C_3 H_8$, the molecular construction of these is represented thus :



$$CH_2\begin{array}{l}\diagup CH_3\\ \diagdown CH_3\end{array}$$

All the chemical compounds in the series below propane, moreover, may make different substances. For example, there are two butanes, three pentanes and six hexanes. In the process of distilling crude petroleum, which is made up of an inconceivably complicated mixture of various elementary compounds named above, those near the top of the list are driven off first, and it is possible to obtain a distillate of any desired specific gravity between 0.60 and 0.90, and of any desired boiling point between about 60° and 606° Fahr. by varying the process of distillation; but no one of these distillates will be found to contain any one or two of the series only. It may contain many of them, and its physical properties will be determined by its average composition or average place in the series. The ordinary commercial products obtained by distillation from crude petroleum with their boiling points, fire-tests, specific gravity, and density, by the Beaumé scale, are shown graphically in the accompanying Fig. 1, and in more detail in the fol-

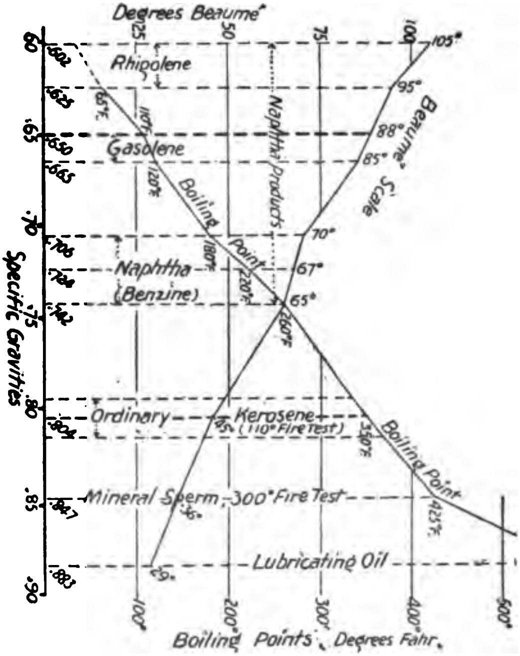


Fig. 1. Diagram of Certain Physical Properties of the Various Commercial Distillates of Crude Petroleum.

lowing Table I, which also gives the proportion of each product which ordinary crude petroleum affords:

TABLE I—PROPERTIES OF THE VARIOUS COMMERCIAL DISTILLATES OF CRUDE PETROLEUM.

	Specific gravity.	Beaumé test. *	Boiling point, Fahr.	Fire test, Fahr.	Per cent. of total product.
Rhigoline	.602 .625	95°@105°	65°		in-sig't
Gasolines:					
For carbureters	.65	88°	110°	....	.07
Ordinary	.665	76°	120°	..	1.3
Naphthas:					
C For street lamps, etc	.706	70°	180°	....	8.0
B For sponge lamps	.724	67°	220°	..	2.5
A Benzine	.742	62°@65°	260°	....	2.5
Tot'l of "naphtha prod'ts"		....	....	...	15.0
Kerosene oil	.804	45°	350°	110°	70.0
Mineral sperm oil	847	36°	425°	300°	10.0
Lubricating oil	883	29°	575°		5 0
Paraffine wax	.848	....	......	....	
Solid residuum	....	....	......	....	
To'l of m'k'table products	....	....	......		100.0

Loss in producing from crude petroleum, say, 10%.

Various other intermediate products are manufactured, for, as we have said, an oil of any gravity desired, within the limits of the above table, can be

---

*The Beaumé scale is the reading of the so-called Beaumé hydrometer, which reads 0° in water saturated with 10% of pure salt, and 10° in distilled water at 51½° Fahr. (10° R.); 20° B. = .928 sp. gr., 30° B = .867, 40° B. = 817, and so on up to 100° B. or more, as shown in Fig. 4. The Beaumé scale for fluids heavier than water is different, starting with 0° in distilled water, and running up to 72° B. for 2,000 sp. gr.

had by varying the process of distillation. Thus, the oil commercially known as "signal oil" is of about 250° fire test, and the commercial "headlight oil" is of 175° test, and both are largely used. Therefore, it is natural that the percentage of the various products should vary somewhat both with the crude oil and the demand for the several products, but the above is about the present average of the United States as nearly as we can ascertain, and it can be varied only within narrow limits. Formerly the percentage of the gasoline products was less, and of kerosene greater.

The government statements of petroleum exports have on them the following standing announcement, from which it would appear that the percentage of the lighter petroleum products is not so large as above estimated:

> It is stated on good authority that the distillation of 100 galls. of crude petroleum will yield 76 galls. of illuminating oil, 12 galls. of gasoline, benzine or naphtha, 3 galls. of lubricating oil and 9 galls. of residuum.

The present yearly crude petroleum product in this country may be taken as about 30,000,000 bbls. (of 42 galls.) as a maximum, of which about half is now from Ohio and other outlying fields. This product has been increasing very slowly indeed since 1880, when it was 26,286,123 bbls., the increase prior to that time having been very rapid. The average wholesale prices of refined petroleum and of naphtha in cents per gallon in New York have varied about as follows:

Year,	1881.	1882.	1883.	1885.	1887.	1888.	1890.	1891.
Petrol'm.	8.0	7½	8¼	8.0	6¾	7½	7¼	7.0
Naphtha.	...	...	$5\frac{15}{16}$	$7\frac{3}{16}$	$7\frac{13}{16}$	7¼	7.85	8.0

At the present time about 12,000,000 bbls. of petroleum per year are exported, chiefly in the form of refined oil, the price of which is but a small fraction of a cent above the crude.

The quantities of these several products, which are now produced or producible in the United States may be approximately stated as follows:

TABLE II.—ESTIMATED PRESENT YEARLY OUTPUT OF THE SEVERAL PETROLEUM PRODUCTS.

	P. c. of total product.	P. c. of crude oil.	Bbls. of 42 galls. per year.	Present value per gall. cts.
Gasoline of 88° proof....	0.7	0.63	189,000	15.
" 76° to 85° "	1.3	1.17	351,000	....
Naphthas................	13.0	11.60	3,510,000	8.
Kerosene oil.............	70.0	63.00	18,900,000	7 2
Mineral sperm oil.......	10.0	9.00	2,700,000	9.2
Lub. oil, etc.............	5.0	4.50	1,350,000	....
Waste in refining.......	....	10.00	3.000.000	....
Total crude oil product, say,		100.00	30,000,000	6.83

All the above products are now merchantable products, and in large demand. As may be inferred from the fluctuations of price given above, the use of the naphthas and gasolines, especially (which were formerly in large degree waste products), has now greatly extended, so that their price ranges considerably higher than the heavier and more abundant products. As will be seen more fully later, to supply all the passenger cars in the United States with gasoline for lighting uses would require an average of 450 bbls. (of 42 galls.) per day, or 164,250 bbls. per year, to which add 20% for wastage, and the total becomes 197,100 bbls., or somewhat over the possible total product.

The chemical nature of the fixed gas (oil gas) produced by the destructive distillation of crude petroleum we need not now stop to consider, since its composition does not vary with momentary conditions. The nature of the gas produced by passing air through gasoline, however, varies greatly with the surrounding conditions, and must be briefly indicated.

The so-called "vapor tension" of gasoline, *i. e.* the proportionate quantity of the spirit which can exist dissolved in air or other gas, and be permanently retained therein without being deposited in a fluid condition, varies greatly at different temperatures below its boiling point of 110° to 120° Fahr. According to figures given in KING's "Treatise on Coal Gas," which is an elaborate and standard work, it is such as to permit the following percentages of gasoline to be thus retained at different temperatures:

Percentage of the Vapor of Gasoline (88° B.) which can be retained in Air at Different Temperatures:

Temperature of air.	Per cent. of gasoline retained.
14° Fahr	5.7
32° "	10.7
50° "	17.5
60° "	22.0
63° "	27.0
104° "	39.0

These percentages are shown graphically in the the accompanying diagram (Fig. 2), from which it will be seen that about 40% of gasoline is the utmost which can be said to be carried off or dissolved in air below the boiling point of gasoline. Above that boiling point (110° F.) the gasoline is converted into steam, and any percentage whatever may be mingled with air. As already stated, and shown more fully below, it would appear from our tests that in the gas produced in practice by the so-called carbureter system the relative quantity of air to gasoline is many times less than the above table calls for.*

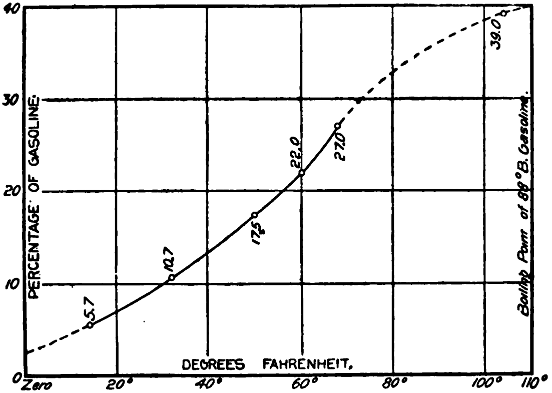


Fig. 2. Percentage of the Vapor of Gasoline Retainable by Air at Various Temperatures.

---

* The percentage of gasoline to air in the ordinary fixed gasoline gas plants is about as the above diagram (Fig. 2) calls for. Thus, in some extensive and unsuccessful experiments in London, made by an "Air Gas Co." in 1872-74, as detailed in KING's "Treatise on Coal Gas," 1,000 cu. ft., or 76.5 lbs., of air was charged with 4 galls, or 21.76 lbs., of 88° gasoline, or 28½%, the temperature being about 70° F., and the resulting candle power for 5 cu. ft. per hour about 16 c. p., but the loss of illuminating power was very great as the temperature fell, a fall of 20° resulting in a loss of about one third of the illuminating capacity. In absorbing the gasoline the 1,000 cu. ft. of air expanded to 1.100 to 1,200 cu. ft., when it gave 240 hours of 5 cu. ft. and 16 c. p. flame, whence the c. p. hours per lb. of gasoline were 176 7, and per oz. of gasoline 11.04, which we will compare with other records later.

What further details are of importance in reference to the nature of the illuminants we shall more conveniently reach later.

PHOTOMETRIC INSTRUMENTS USED AND MANNER OF TESTING.

The instrument used in the photometric tests was

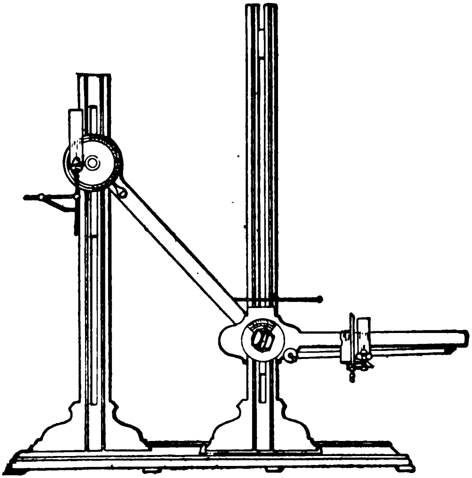


Fig. 3. Dibdin's Radial Photometric Apparatus.

the "radial photometer" of W. J. DIBDIN, F. I. C., F. C. S., Chemist to and Superintendent of the Gas and Gas Meter Testing Department, Metropolitan Board of Works, London, which is described in full in the *Journal* of the Society of Chemical Industry, Vol. III, page 277. The apparatus is shown in outline in Fig. 3. Mr. DIBDIN shows most clearly that the ordinary method of testing lights by horizontal measurements alone gives not only misleading but erroneous results. The record of the intensity of the emitted light in one direction, the horizontal, can only be of value when those rays alone are to be utilized in practice, and the results of such a test are useless, or worse, when the light is to be used at a point above or below the source of illumination.

The usual form of photometer is constructed to give the candle power in this horizontal direction only; but to really cover the required ground it is desirable to use the special instrument illustrated, or some equivalent. The principles upon which this instrument is constructed are as follows:

When two lights are opposed to each other in a horizontal direction, and a vertical screen is placed between them, it is evident that the rays impinging on them must do so in accordance with the well-known law of the squares of the distance. If the actual distance from the center of the screen remains constant while traveling through the circumference of a circle whose center is coincident with the center of the screen, the number of rays impinging upon a unit area of the disc must be less and continue to decrease as the position of the light is increased from that of the horizontal line; and this decrease is in exact ratio to the cosine of the angle formed by the position of the light with regard to the disc and the path of horizontal rays. Therefore the number of rays impinging upon the vertical disc will diminish with the cosine of the angle thus formed. The following diagram (Fig. 4) shows this clearly.

Let *A A'*, *B B'* represent the section of horizontal rays impinging at right angles upon the vertical disc *C C'*, and let *C D*, *C' D'* represent the section of an equal number of rays thrown at a downward angle from a source of light placed above the horizontal. It is evident that the whole of the angular rays do not impinge upon the disc, *C C'*, but that the

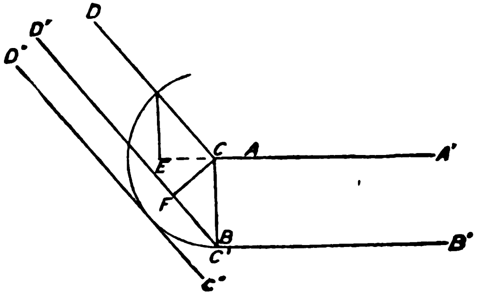


Fig. 4.

rays that do so are defined by *C D*, *C' D'*. By drawing the circumference of a circle whose radius is *C C'*, and finding the cosine *C E*, it is at once seen that the section of the rays *C F* which impinge upon the disc is in exact proportion to the cosine of the angle of incidence, *C E*.

It is evident from the foregoing that the disc used must be arranged so that the angle of incidence be equal on either side, as outlined in Fig. 5, in which *A A* represents the disc, *A B* and *A' B'* the horizontal rays, and $C\ A$, $C'\ A'$ the angular rays. With the disc arranged in this way it is evident that the loss of light by reflection is equalized.

The "radial photometer" of Dibdin, as illustrated in Fig. 3, and which operates on this principle, consists of two vertical supports, one of which is permanently fixed to the baseboard or foot, while the one on the right hand travels on rollers on the baseboard in such a position that it will run in front of the fixed support. The two uprights are connected by a bar the ends of which work on axles attached to blocks which travel in the grooves of the uprights.

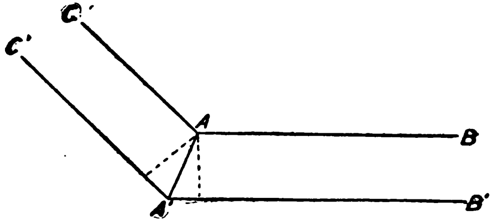


Fig. 5.

The centers of the axles correspond in position with the centers of the two graduated dial plates in front of the uprights. It is therefore evident that in whatever *position* the bar may be, the *distance* from the center of one dial to the other must be constant. In front of the dial plate on the traveling upright the screen or disc-holder is fixed so that its center is coincident with the center of the dial. The arrangement of the traveling standard on the graduated bar is evident from the sketch.

The disc used is the "star" or Leeson disc. This has been found to give the most exact readings with lights of slightly different colors. The arrangement of the screen to cut off extraneous light is not shown, but can easily be devised by the operator.

Standards.—The Methuen screen was used as a standard, carefully tested against standard candles before and after each day's work. The candle power of the standard was varied according to the lamp being tested, and was found to possess all the requirements of a practical standard.

The special plant used for measuring the consumption of illuminant by the Frost carbureter light is outlined in Fig. 6. This plant, as hereafter more fully shown, consists of a large "carbureter" of peculiar and ingenious construction, filled with wicking saturated with gasoline. This carbureter is placed on the roof of the car directly above the lamp, and through it a supply of air under slight pressure is driven to form the gas. Just before entering the carbureter the air passes through a coil just above the lamp, where it is heated, and thence it circulates through the carbureter and descends to the lamp beneath, charged with gasoline, where it is burned.*

In order to get the weight of the gasoline and amount of air consumed, the lamp and carbureter were attached to a platform, which was supported by four iron posts placed on a platform scale, which was accurate and sensitive to 1 oz.

The air supply came from the air tank through the usual regulation, and thence was measured by a new standard meter constructed so that, as is usual, the number of feet of air consumed per hour is indicated by readings of one minute. The actual readings were of longer duration, however, to secure greater accuracy.

---

* The coil and the heating of the air supply have been abolished recently, as noted hereafter.

The total weight of the apparatus before test was	235 lbs. 13 oz.
The weight at expiration of test was	225 lbs. 7 oz.
Amount of gasoline consumed	10 lbs. 6 oz.

This is equal to 1.92 galls. of gasoline of 88° B., or 0.65 sp. gr., which weighs 5.421 lbs. per gall. At 15 cts. per gall. this amounts to 28.8 cts. for 41 hours burning, which indicates a cost per hour per lamp of 0.70 cts., to which, however, must be added further allowances for wastage, etc., as we shall see later.

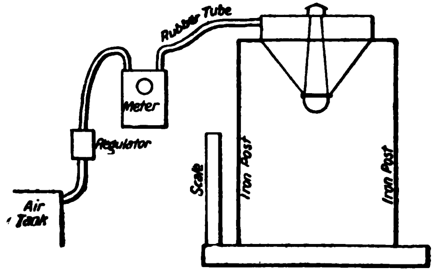


Fig. 6. Arrangement of Frost Carbureter Plant for Purposes of the Test.

The subjoined table shows in detail the consumption of air and gasoline for each hour of the test.

TABLE III.—DETAIL RECORD OF THE CONSUMPTION OF AIR AND GASOLINE OF A FROST CARBURETER.

FULLY CHARGED WITH GASOLINE, ACCORDING TO PRINTED INSTRUCTIONS, AND BURNED UNTIL EXHAUSTED.

[The summations given indicate the end of periods of continuous burning, which occupied parts of seven (7) different days. The double readings of air meter show the readings at beginning and end of the first hour.]

Hour.	Amt. of gas'l.	R'ad. of air m't'r.	H'ur.	Amt. of gas'l.	R'ad. of air m't'r.	H'ur.	Amt. of gas'l.	R'ad of air m't'r.
	oz.	cu.ft. per h.		oz.	cu.ft. per h.		oz.	cu.ft. per h.
1	5	1.7 1.7	16	4	1.9 1.5	31	4	4.0 3.0
2	5	1.4	17	4	1.7	32	4	2.4
3	4	1.	18	3	1.4	33	4	2.12
3h.	14	4.45	19	3	1.5	34	3	2.
4	5	1.7 1.4	20	3	1.4	4h.	15	10.52
5	5	1.	21	3	1.3	35	4	4.0 3.0
6	4	.75	22	3	1.2	36	4	2.8
7	4	.6	7h.	23	10.35	37	4	2.3
8	4	.5	23	4	3.13 2.32	38	4	2.3
9	3	.5	24	4	1.84	39	4	2.40
6h.	25	5.35	25	4	1.76	40	3	2 41
10	5	2.0 1.7	26	4	1 56	41	3	2.48
11	4	1.5	27	4	1.50	7h.	26	18.45
12	4	1.4	28	3	1.50			
13	4	1.2	29	3	1.44			
14	3	1.1	30	3	1.44			
15	3	1.	8h.	29	14.20			
6h.	23	8.4						

SUMMARY.

DAY OF TEST.	Hours of test.	Gasoline.		Air consumed.		Gasoline per 100 p'rts air.
		Consumed.	Blown out.	Cu. ft.	Oz.	
		Oz.	Oz.			%
First.	3	14	3	4.45	5.47	256
Second ...	6	25	3	5.35	6.58	380
Third.....	6	23	2	8.40	10.33	222
Fourth. .	7	23	1	10.35	11.73	181
Fifth.	8	29	1	14.20	17.47	166
Sixth.....	4	15	1	10.52	12.95	116
Seventh..	7	26	..	18.45	22.69	114
Total...	41	155	11	71.72	88.22	174

Total gasoline consumed..............166 oz. = 1.92 gallons.
Total gasoline which can be retained in air at 100° F . 40%

At the end of the forty-first hour the burner refused to work properly, flaring and smoking badly, and the test terminated. The total amount of gasoline used as illuminant was 166 oz., or 10 lbs. 6 oz. The amount of gasoline lost by blowing off was 11 oz., as follows:

Loss at the end of 3d hour burning..................	3 ozs.
“ “ 9th “ “	3 “
“ “ 15th “ “	2 “
“ “ 22d “ “	1 “
“ “ 30th “ “	1 “
“ “ 34th “ “	1 “
	11 “

TABLE IV.—COMPARATIVE SUMMARY OF FIRST AND LAST HOURS OF EACH BURNING.

[Abstracted from Table III.]

DAY.	FIRST HOUR.			
	Gasoline.	Air.		Gasoline per 100 parts of air.
	Oz.	Cu. ft.	Oz.	
First........	5	1.7	2.09	239
Second.	5	1.55	1.91	262
Third.	5	1.85	2.28	219
Fourth.	4	1.70	2.09	191
Fifth........	4	2.72	3.35	119
Sixth.	4	3.50	4.32	92½
Seventh	4	3.50	4.32	92½
Total.	31	...	20.36	152

DAY.	LAST HOUR.			
	Gasoline.	Air.		Gasoline per 100 parts of air.
	Oz.	Cu. ft.	Oz.	
First........	4	1.0	1.23	325
Second.	3.5	0.5	.62	56½
Third.......	3	1.9	1.23	244
Fourth.	3	1.2	1.48	203
Fifth.	3	1.41	1.78	169
Sixth.	3	2.0	2.46	122
Seventh....	3	2.48	3.06	98
Total.	22.5	....	11.86	189

To properly interpret and understand Tables III. and IV., some explanations and comments are needed, which we postpone till some further facts including the record of still another test of this same character under slightly different conditions, have also been given.

[NOTE.—At this point the consecutive publication of the several parts of the article, as announced in the beginning of it, was interrupted in order to enable some further tests of the carbureter plant to be made, to determine if certain differences of practice in the Frost dry carbureter plant as introduced and used on the Pennsylvania R. R. and as sold and used by the Railroad Lighting and Manufacturing Co. had any effect upon the practical working of the apparatus, and if so, what. The publication of the photometric tests was therefore postponed until the new tests had been completed, and the description of the several plants taken up and completed before the photometric records and notes of cost, safety, etc., were given.—ED.]

THE FROST DRY CARBURETER PLANT.

The Frost "dry carbureter" plant, like all other plants as yet devised for using air charged with the vapor of gasoline as an illuminant, consists in its purpose and essence of a device for passing air under slight pressure through a chamber packed with cotton wicking soaked with gasoline, and thence passing it as quickly as possible, and with as little change of temperature as possible, to the burner, where it is burned like other gas.

Fixed plants of this general nature for lighting isolated houses and hotels are in very extensive use, as is well known, and while a variety of distressing accidents (the nature of which we shall consider later) have from time to time occured, and doubtless will continue to occur, yet they have not been so frequent as to prevent the increasing use of the system, nor to seriously, if at all, affect the insurance rates asked on buildings so lighted. It is proper to add that the insurance companies ignore a good many real differences of security in fixing rates, as for instance, the difference between fire-proof and ordinary wooden construction in many buildings, and that they very jealously and rigidly scrutinize gasoline lighting plant, which must be acceptable in all respects, or they will not insure at all. Nevertheless the facts of their practice are significant.

For lighting railway passenger cars any plant of the nature of the ordinary fixed house plant would be wholly inapplicable, because of its danger in a portable form, and special precautions are necessary. The prominence of the Frost dry carbureter plant as a system of car lighting arises from the special success with which that system has met the peculiar requirements of the case, eliminating many of its more serious dangers, and so placing it ahead of any other system of gasoline car lighting which has ever been devised. Whether it should or should not be admitted as a standard system for general use depends largely on a variety of facts yet to be considered. For the present we confine ourselves to the mechanical details of the plant, and in regard to these details one can only speak with praise. It is risking little to say that if the Frost system is not a suitable and expedient one for lighting cars, no such system using gasoline as an illuminant can ever be devised, and that a case of great apparent strength, at least, can be made out in its favor. Its peculiar and especial merit is that the gasoline is not carried in a liquid form, but absorbed in a mass of wicking, which is inclosed in a tough copper carbureter which seems to exhaust all the possible precautions for carrying the gasoline safely.

In its original form, as it stood in 1885–86, the system was quite different from its present form. The carbureter was then a brazed copper tank placed under the car, filled with wicking saturated with gasoline, and with partitions to compel the air to meander back and forth through the wicking. This carbureter was encased in a wooden box, which was heated in winter by a pipe from the car-heating apparatus. Compressed air from the brake pipe entered (1) a storage reservoir, (2) a reducing valve to 1-lb. pressure, (3) the carbureter, (4) a second reducing valve (to 1 oz.) and thence to the burner.

Despite some enthusiastic descriptions of the apparatus, which appeared at that time in various technical papers, praising the plant in the highest terms, this apparatus in this form was not successful, owing chiefly to the difficulty of insuring a proper and even temperature in the carbureter and air supply. In cold weather the light became quite dim and irregular, the light was not brilliant and other serious difficulties arose with it.

The Pennsylvania R. R. began its experiments on the plant in this form over seven years ago, in the spring of 1884, and its subsequent development into the form which the system now has resulted largely from experiments made on that road.

The Pennsylvania began equipping cars with the plant as finally perfected about three years ago, in the summer of 1888. The first car in the country to be equipped with the light, we believe, was one on that road. A year ago the Pennsylvania R. R. had some 250 cars equipped, the Pennsylvania Co. 50, the Reading 55, the Norfolk & Western 47, the Union Pacific 35, the Kansas City, Fort Scott & Gulf 25, the New York, Ontario & Western 17, the Chicago, Burlington & Quincy 13, the N. Y., Susquehanna & Western 8, the Cumberland Valley 6, the East Tennessee, Va. & Ga. 5, a total of 511, besides which there were a few others. Since then, we are informed, the Pullman Palace Car Co. and several others have begun equipping cars on a pretty large scale, and it is still conspicuously advertised by the manufacturers that the system is "The Standard of the Pennsylvania Railroad," but we do not understand that that road adopts any standards in any formal way other than to make standard plans for anything and everything which it puts into use, and we are informed that this claim is made without the knowledge or authority of the Pennsylvania road and contrary to instructions forbidding such use of its name, as also that only a small percentage of the cars of the road are as yet equipped with the plant.

By courtesy of the Railroad Lighting & Manufacturing Co. we are enabled to present the following statement as to the cars which they have equipped to date:

Western Railway of Alabama..........................	20
Atlantic Coast Line....................................	3
Baltimore & Ohio Railroad...	1

Canadian Pacific Railway	2
Central Railroad of Georgia	3
Chicago, Burlington & Quincy Railroad	13
Chicago, Milwaukee & St. Paul Railway	2
Chicago, Rock Island & Pacific Railway	1
Chicago & West Michigan Railway	4
Cumberland Valley Railroad	10
East Tennessee, Virginia & Georgia Railway	5
Georgia Southern & Florida Railroad	1
Kansas City, Ft. Scott & Memphis Railroad	25
Lehigh Valley Railroad	1
Louisville & Nashville Railroad	1
Michigan Central Railroad	1
Minneapolis, St. Paul & Sault Ste Marie Railway	1
New York, Ontario & Western Railway	25
New York, Susquehanna & Western Railway	15
Norfolk & Western Railroad	50
Old Colony Railroad	4
Pennsylvania Railroad	450
Philadelphia & Reading Railroad	60
Pittsburg, Cincinnati, Chicago & St. Louis Railway	25
Pittsburg, Ft. Wayne & Chicago Railway	25
Pullman's Palace Car Company	50
South Carolina Railway	10
Union Pacific Railway	50
Victorian Railways of Australia	2
Wisconsin Central Railway	10
Total	870

Nine-tenths of these cars have been equipped within the past two years, and we think that you will concede, taking everything into consideration as to introducing our light and educating the railways to its advantages, that we have made considerable headway in this respect. The prospect of a greatly increased business for the near future is very encouraging, especially for cars for the principal trunk lines, as we have now quite a number of important negctiations under consideration. The Pullman Co. have practically adopted it as their standard, and the outlook for a very large business from them is certainly very gratifying.

The company certainly has made very considerable and creditable progress, and they are entitled to all the presumption in their favor which is created by the fact that ten different companies have equipped 20 or more cars, indicating that the system has been more or less decisively approved by them, while 20 other companies have experimentally applied it to from 1 to 15 cars.

The carbureter plant as perfected and now manufactured is shown in detail in the accompanying illustrations, Figs. 21–33. Certain modifications or differences of practice as to some details have arisen within the last year or two between the Pennsylvania R. R. and the manufacturers of the Frost plant (the Railroad Lighting & Manufacturing Co , Philadelphia, Pa.) which we shall also note. Some of the accompanying illustrations show Pennsylvania R. R. practice only.

Fig. 21 shows the general arrangement of the plant. A branch from the brake pipe leads through a check-valve and dust screen (Fig. 22) to an air tank (Fig. 23) where a supply of air at the ordinary train-pipe pressure is stored, the check-valve preventing return of the air when the brake-pipe pressure falls for application of brakes. A "tank needle-valve" (Fig. 24) is used when it is necessary to cut off all air supply from the tank, as for repairs or any breakage. Thence the air is piped into the closet, where there is an air gage to indicate the tank pressure, and a closet valve very similar to Fig. 24 for cutting off air supply. Thence the air passes to the regulator or reducing valve, the original form of which (the Bowman regulator) is shown in Fig. 25, while the form now in use, the Chapman regulator (which works on the same general principle as the Pintsch

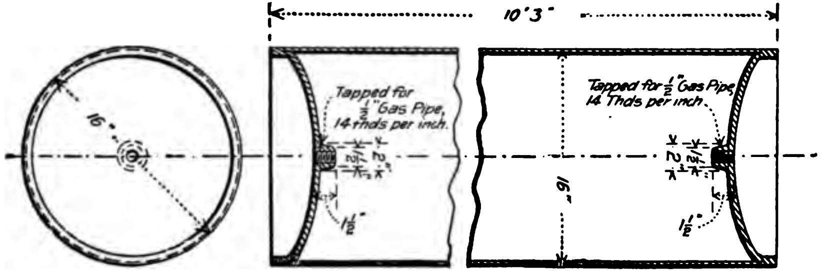

10' 3"
16"
Tapped for ½" Gas Pipe, 14 thds per inch.
1½"
Tapped for ½" Gas Pipe, 14 Thds per inch.
16"
1½"

Fig. 23. Air Tank. P. R. R. Standard.

regulator) is shown in Fig. 26. Since these articles were begun the company has adopted still another regulator of its own, which it prefers to the Chapman. A second dust guard was formerly used just before the regulator, but this is now omitted. In the regulator the air pressure is reduced to 3 lbs. and here first the air comes into potential connection with the gasoline, which is contained in the "carbureters," to be hereafter more fully described, which are now placed on the outside of the roof directly over each lamp. All the pipe connections are of copper. A second check-valve is used beyond the regulator to keep gasoline vapor from entering it.

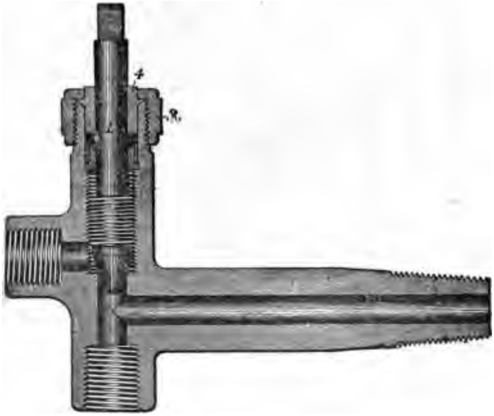


Fig. 24. Tank Needle Valve.

A ⅝-in. drawn copper tube runs from the regula-

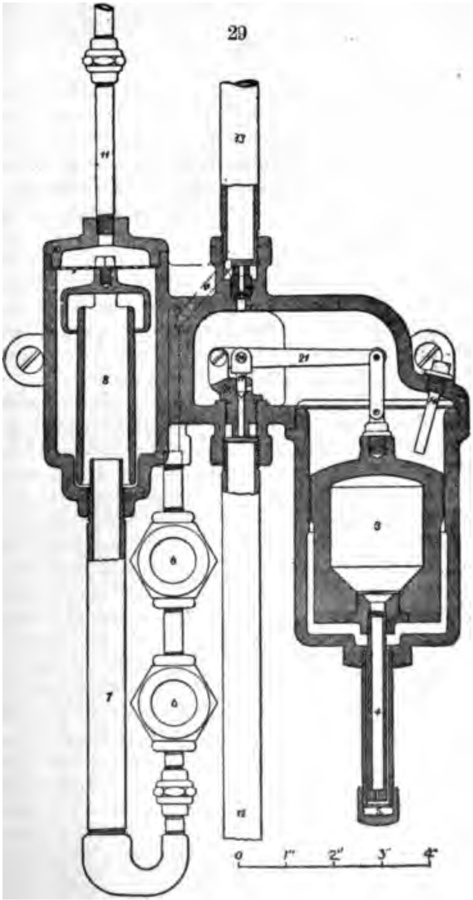


Fig. 25. Bowman Regulator and Indicator.

tor the whole length of the car, along the carbureters, with each of which it has an open T connection. After passing the last carbureter the tube terminates in a mercurial safety-valve (Fig. 27) set at 5 lbs. pressure, thus giving a margin of 2 lbs. pressure to "go and come on" in service before vapor escape through the valve.

Under these conditions it will be seen that the long copper tube from regulator to safety valve, inclusive, and the interior of the five or more carbureters down to the cock of the burner, constitute a single open chamber under 3 lbs. pressure, which may at times rise to, but not above 5 lbs.

There was formerly placed in the closet a mercurial "indicator," to show when the carbureters were approaching exhaustion and needed refilling. On the Pennsylvania road, where this device originated, it is still used. It was based upon the principle that through a hole of fixed size an increase of air supply can only be obtained by increasing the pressure, and also upon the observed fact that as the carbureter approached exhaustion a larger supply of air is required, because the gas is poorer and the lamp needle-valves must be opened wider to give the same light. The whole air supply was therefore passed through a hole (about $\frac{1}{32}$ in. in diameter) which would let through enough air supply for full carbureters with a very trifling difference of pressure, but which required considerable pressure (some 4 ins. of mercury) to let through air enough for nearly empty carbureters. This indicator is shown in part in Fig. 25. Two little glass disks enable the height of a mercurial

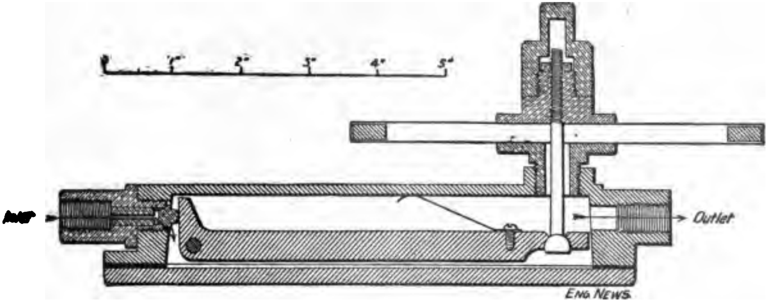


Fig. 26. Chapman Regulator.

gage, which registers this difference of pressure, to be seen, and when the difference reaches a certain point (while the lamps are burning full) it is to be taken as a signal to "Fill Carbureters" and a sign to that effect is displayed. There is naturally no way of telling by day, or except when the lamps are burning, whether the carbureters need recharging or not.

This index gage has lately been abandoned, and the following simpler one introduced, viz.: "When the flame of the lamp begins to divide into separate jets, it indicates that the carbureters need recharging; then turn the disk on the indicator board until the words 'Fill Carbureters' appear." We are informed by the manufacturers that the present (Star) burner begins to divide into separate jets from 8 to 10 hours before the complete exhaustion of the carbureter, while the mercurial indicator was not found to be sufficiently accurate, and hence could not be depended on. We shall hereafter see reasons why the mercurial gage was of necessity likely to give wrong indications. As the new indicator is much the simpler, and is also more accurate, it is a decided improvement.

THE CARBURETER.

We now come to the carbureter. The main features of its construction as used on the Pennsylvania R. R. are shown in Figs. 28, 29. The construction now favored by the manufacturers differs in some details as hereafter noted. The abuse to which this part of the plant can be be subjected without destruction is graphically shown below. It is difficult to imagine what more can be done than has been done in this device to make the carrying on cars of gasoline for lighting purposes safe and secure; yet, on the other hand, the tests illustrated in these cuts do not, in our judgment, subject the carbureter to as severe treatment as it may have at times in railway accidents. We describe the round carbureter, as the one tested by us. A large square carbureter has lately been introduced as noted below.

The carbureter proper is made of No. 18 cold-rolled copper, about $\frac{1}{16}$ in. thick. The bottom and sides are struck up by a die in one piece, without soldering. The compact mass of wicking filling is then placed *en masse* inside of the copper shells, being put together as follows:

Two parallel plates, 4 ins. apart, are perforated by a series of ()-shaped holes for the wicking, as may be seen in part in Fig. 28, these holes being arranged to form a spiral like that shown in plan in Fig. 29. These plates are then connected by a continuous strip of metal, soldered in a spiral to both the parallel plates along the lines shown in plan in Fig 29. The interior frame, or head, is then ready for the wicking, which is put in by boys with much dexterity, strand by strand, and cut off so as to make a tolerably smooth surface, called the "mat."

This interior filling, which is to all appearance a mere solid mass of partly compressed wicking (except that wicking is left out of the three or four holes nearest to the air inlet and gas outlet), is then forced into the copper case, which requires considerable pressure, as the fit is tight, and the top cover-plate of copper is then put on, and fastened by the very careful and elaborate joints which are sufficiently shown in Fig. 28. The similar arrangements for inserting the central tube (5¼ ins. in diameter) and the several air and fluid openings we need not stop to particularize.

About 12 lbs. of wicking (of the best grade) are thus used for each carbureter, the weight of the copper used per carbureter being 18½ lbs. and the total weight of each carbureter complete (apart from its outer case) being 33 lbs. The four gallons more or less of gasoline which the wicking will absorb will weigh some 21¾ lbs. more. The outer casing or mantle, which serves at once for protection from injury, for keeping off the solar rays, and for furnishing a chamber in which hot air from the roof of the car and part of the products of combustion may circulate around the carbureter and keep it warm, is then added. This casing, or "mantle," is made of a double thickness of ordinary kalamein iron, packed between with straw board so as to be ¼ in. thick in all. The bottom of the outer case consists of a single sheet of kalamein iron. The carbureter complete is firmly fastened to the roof of the car by the straps 23 and bolts 25, Fig. 29.

The openings into the carbureter are (1) the charging appliance, consisting of the filling valve and the discharge valve, 16, 18, Figs. 28-9, shown in more detail in Figs. 30, 31; (2) an opening (5-17, Fig. 28) by which air enters the carbureter near its center, and (3) a gas exit, marked 7-17, near the outside of the carbureter, where the mixture of air and gasoline vapor escapes, to pass through the pipe 8, 9, 10, 11, to the burner. The top of one arm of the lamp, where the gas connection is made, is visible in Fig. 28, and Fig. 32 shows, to larger scale, the carefully made gas-tight joint which is used, and which, so far as we can learn, never gives any trouble by leaking.

Three fundamental details in regard to the carbureter are the air supply, the method of keeping it warm, and the charging arrangements. The air supply under Penna. R. R. practice is shown clearly in Figs. 28, 29. A copper coil of $\frac{3}{32}$ in. interior ($\frac{1}{8}$ in.

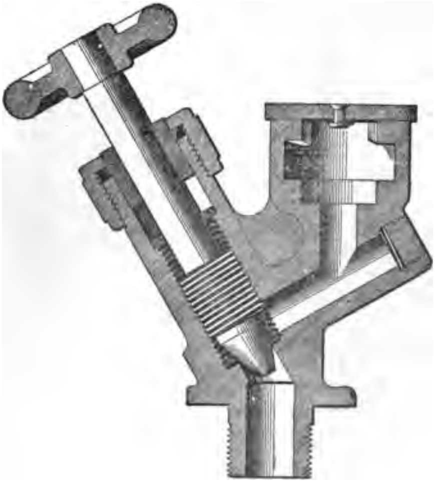


Fig. 30. Filling Valve.

exterior) diameter is placed in the middle of the central space, through which most of the gases of combustion from the lamp go up. The air enters from the deck pipe at the bottom of this coil, and thence,

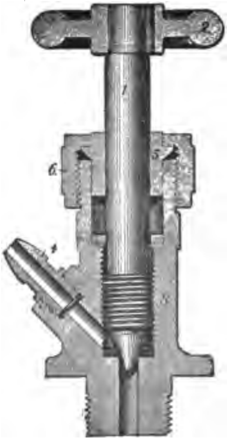


Fig. 31. Discharge Valve.

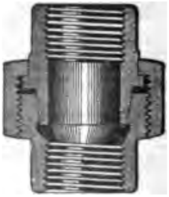


Fig. 32. Joint between Carbureter and Lamp.

after passing throught it, enters the carbureter at the aperture 5. Here the air is compelled to enter into and go through the wicking, if it enters at all, since the air connection is only with the inner part of the spiral. It may, however, follow this wicking downward to the bottom, and thence take a shorter horizontal path through the bottom of the wicking instead of following the spiral, if it can. Or, if the pressure be not sufficient to force it through, as there is back pressure against it, it may do neither the one nor the other. It will obviously take the path of least resistance and is supposed to follow the spiral wicking space. We shall shortly see, however, that the air supply not only does not, but that it cannot, under certain unfavorable conditions at least, either in part or whole, follow the wicking. The air enters from the copper coil at a temperature of 300° to 350° F., but enters in such a small volume that it is undoubtedly cooled down very quickly to the boiling point of gasoline, 90 to 110° F., or below it if the interior of the carbureter is not heated up to that point.

The Frost carbureter company no longer use this copper coil, but enter the air supply from the deck tube directly at 5, a difference of practice which is not approved on the Pennsylvania road. In each case alike, however, there is a further important detail of the air supply yet to be described, viz., the "by-pass," by which a supplementary air supply is admitted to the gas at its exit. This by-pass is clearly shown, but (unfortunately) not numbered in Fig. 28, and lies between the "7" and "$\frac{1}{8}$." The aperture is quite small, $\frac{1}{32}$ in., but it is large enough to supply a very considerable amount of air per hour (much more than appears to be used under any circumstances, as we shall shortly see), without subjecting it to the resistance of the wicking spiral, through which latter, it would seem, little or no air would be likely to pass as long as the demand for air is sufficiently supplied through the by-pass.* Delivery of air through the by-pass also, therefore, can only cease when there is a pressure of steam at the gas exit of at least 3 lbs. per sq. in. If there be a still higher pressure than this, as at times happens with the plant as now supplied by the manufacturers, there will be a tendency for the vaporized gasoline to reverse the current through the by-pass and flow backward into the deck pipe, where it will condense. This fact we shall hereafter have occasion to refer to. The same tendency will arise should the rays of the sun heat the carbureter above the boiling point, but in this case there is not likely to be any condensation in the deck pipe at first, as it will presumably be still hotter. As the sun's rays grow colder, however, the copper pipe will cool with it while the carbureter is still hot, and hence there is then opportunity for a considerable condensation in the copper deck pipe, which is of ½-in. diameter. The most which could happen while the sun's heat is rising or stationary is that the pipe leading down to the burner should gradually fill with condensed gasoline, which would escape in liquid form when it was attempted to light the lamp. We have no knowledge of any incident of this kind having ever occurred; but it is known that gasoline steam is generated by the sun's heat so as to cause a blow-off through the safety valve not infrequently, and whenever such blow-off occurs there would appear to be liability of the lower gas pipe

---

*On the other hand it is claimed that the by-pass and the spiral passage way through the carbureter are two passage ways which the air is at liberty to follow, and the connections to these being opened, the air will follow both passage ways in amount directly proportional to the resistances. Mr. C. B. DUDLEY, Chemist P. R. R., who had a prominent part in the development of the carbureter system, writes us as follows on this point: "It is assumed that the passage way through the spiral is so choked with the wicking, that no air will pass that way, but when the by-pass was first devised, this point was very carefully considered, and experiments were made showing the relative resistances When the aperture to be used in the by-pass was decided on, which is now 1-32 in. diameter, we made a number of experiments on the relative resistance of the passage of air through the spiral and through the 1-32-in. aperture. The absolute amount that passes through the two is not a constant, because when the carbureter is first charged less air passes through the spiral, and relatively more through the by-pass, than when the carbureter is nearer dry, but proportions, as near as we can get at them without making absolute test, are that approximately 10% of the air passes through the by-pass, and the rest of it through the spiral. These figures, as said above, must be regarded as approximate, and as variable, depending on the condition of the carbureter. That some air must pass through the wicking, if not most of it, will appear evident from two or three things: First, the apertures through which the wicking is drawn are ⅝-in., while the sides of the spiral

---

are ⅞-in. apart. There is, therefore, as shown on accompanying pencil sketch, a free passage way for air at the top and bottom of the spiral [of ⅛-in. on each side.—Ed.], even assuming that the wicking when saturated with gasoline fills the spiral near the middle. Experiments can be made on this point, if desired, but we are very confident that the facts are as stated by us. Second, if it be true, that air does not circulate through the carbureter, it would be impossible to light a carbureter lamp at all, unless there was enough pressure inside the carbureter produced by gasoline vapor, to have some go out of the carbureter, without any air going in. We have lighted a carbureter lamp, having a by-pass, and everything according to our standard construction, when there was no fire in the car, and the carbureter had been exposed for two days, to a temperature of 10° Fahr. To our minds this is absolutely conclusive that air goes through the carbureter, for no gasoline vapor would pass out of the carbureter under these conditions, unless something pushed it out."

filling up with condensed gasoline, but very slowly, and probably not injuriously.

To protect the flame of the lamp from downward rushes of air tending to extinguish it (which occurs chiefly or only when brakes are suddenly applied) a cone, 29, is (in P. R. R. practice, and formerly in all practice) put in to divert any downward draft of air, and this also has the effect to slightly check the free escape of hot air and gases up the central tube. An open space, 31, is formed around the central tube, by which the hot air in the top of the car and part of the gases of combustion (in P. R. R. practice a very little part, probably) can escape up into the open space between the carbureter proper and its casing. This hot air spreads about under the bottom space, 27, then rises around the sides, and then returns again to the ventilator, 21, where it mingles and escapes with the gases arising through the central passage. By decreasing the freedom with which air escapes from the ventilator, the temperature which the carbureter normally attains can be increased up to any temperature which the flame of the lamp below can maintain.

This the manufacturers of the plant now prefer to do. As will be seen from the accompanying drawing of the lamp now used (the "star burner," Fig. 33), a solid diaphragm, perforated with comparatively small openings only, is placed directly above the lamp chimney, through which perhaps half of the gases of combustion pass directly up the chimney, and the remainder of these gases, mingled with a certain amount of the heated air in the top of the car enters the annular side passage only (131, Fig. 28), and thence circulates around the carbureter, thus tending to heat it somewhat warmer than does the arrangement of passages shown in Fig. 28.* How great the resulting difference of temperature may be is now being made the subject of experiment, and we shall be better able to speak later. The manufacturers claim that the arrangement as to the exit of gases, shown in Fig. 33, is preferable to that of Fig. 28 for another reason, viz., that sudden shocks, as in switching, will at times cause a downward puff through the ventilators which extinguishes the lamp.* We are not accurately advised as to the extent of this danger with the arrangement of Fig. 28, nor of the extent to which it is remedied by the arrangement of Fig. 33, but it is obvious that there may be considerable difference, since there is a clear annular space around the cone 29, Fig. 28.

---

* The manufacturers explain the motive for the omission of the copper coil and the change in the smoke-bell as follows:

We found in practice that there was no perceptible advantage to be gained by the use of the copper coil, owing to the fact that the hot air would not travel any great distance before it had lost all the heat given to it in passing through the coil, and we disposed of its use for this reason, and also because it reduces the cost of manufacture. At the same time we are putting it in all the carbureters for the Pennsylvania R. R. and auxiliary lines, as they desire it as their standard, and we have no objection to its use. With our new style of inverted lamp the heat does not strike this copper coil as direct as it otherwise did with the old argand burner, consequently we gained nothing by its use, and we disposed of its use in February, 1890, when we adopted the inverted regenerative lamp as our standard.

In regard to changing the smoke-bell and introducing a perforated plate, it was necessary to make this change in order to prevent the lights from being blown out, caused by either an excessive upward or downward draft through the ventilator flue, which was generally caused by the opening of doors before the train stopped, and then by the sudden application of the air brake by the engineer when he found that he was running past the station, and the brakes were not released until after the train had come to a standstill, thus causing a sudden suction, and the improved perforated plate or smoke-bell prevented, to a great extent, the extinguishing of the lights under these circumstances; it also diverted more of the heat around the carbureter, which was a very good feature, as it keeps it at a more even temperature.

The great toughness and strength of the carbureter, a detail to which great weight is very properly attached, as indicating that no serious harm is likely

---

We have made no change in the by-pass opening [which is $\frac{1}{32}$ in.—ED.]. In regard to contracting the exit for hot air through the ventilator we reduced the height of the ventilator owing to the fact that with the old style the carbureter measured 12 ins. high over all. This height was so great that we could not apply it to ordinary cars in the West, owing to the limited clearances, and also because of limited clearances in the New England states. The openings through this carbureter are from 10 to 15 times greater than the flue of the lamp; we have even gone further than this, and in some cases reduced the height of the ventilator to 1½ ins. above the carbureter as compared with the 6-in. ventilator first designed by the Pennsylvania R. R. Co.

In making these changes we have always endeavored to have from three to four times the opening in the ventilator that we have in the lamp chimney, and this, we think, is sufficient to take care of all heat from the cars. We have also made this change in the ventilator openings owing to the fact that the Western roads complained that the openings were so large in the old-style ventilator that there was a reverse draft downward through the flue which was very annoying to passengers, and cooled off the car excessively in cold weather. All of these improvements that we have made in the system since its adoption have been greatly to its advantage, and it has made the system applicable to all styles and classes of cars for all roads. The changes are never made hastily by us, and are only decided upon after very careful consideration and thorough practical test.

*The older styles of lamps only were put out in this way, we are informed. The new inverted lamp is only caused to flicker or jump by this cause, but never goes out.

to result from the carbureters even in accidents, is shown in the six following engravings:

Fig. 34 shows a new 25-in. diameter carbureter, with the top of the copper casing cut open and the top perforated plate torn free from the wicking and the spiral partition to which it is soldered, to expose its internal arrangement of perforated top and bottom plates, spiral passage and wicking used for

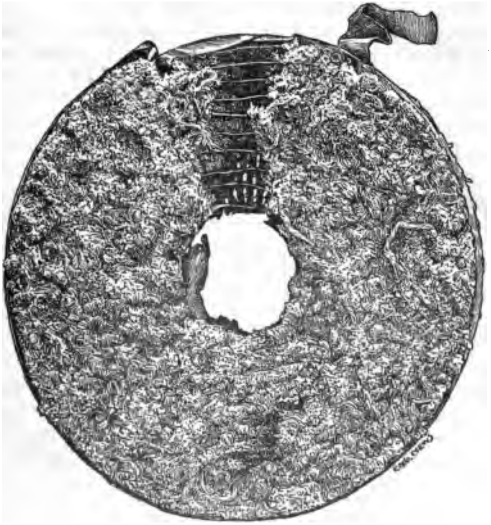


Fig. 34. New Carbureter Cut Open to Show Wicking and Interior Construction.

holding gasoline in saturation, which it will be seen must necessarily constitute a very solid mass, so connected together by the partitions and top and bottom plates as to be likely to hold together, even if the copper casing were violently torn off.

Fig. 35 shows a new 25-in. carbureter after it had first passed through a fierce fire of shavings and yellow pine kindling wood saturated with coal oil, and then been torn open to show its condition. This carbureter was first fully charged with 4 galls. of 88° B. gasoline, and then through a deck air pipe with a mercurial safety valve on the end charged with air pressure at 3 lbs. per sq. in., as in service. It was then mounted on iron supports and the fire started. In a couple of minutes the pressure soon rose above 5 lbs. per sq. in., at which the safety valve blows off, and vaporized gasoline began escaping from the safety valve, which was placed so near the fire that the escaping gas soon took fire and burned like a torch, the mercury being all evaporated. Thereafter from 1 to 3 lbs. pressure was indicated, being the pressure at which sufficient velocity of exit was obtained to let out all the steam generated. Had all not escaped, the pressure would have gradually risen, and with it the velocity of exit. The carbureters are tested to 20 lbs. pressure and it takes 60 lbs. to burst them. The outer mantle became loosened and twisted and little jets of gasoline steam escaped through holes where the solder was melted away. and took fire; but, though the heat of the fire was so intense that the 1½ in. iron pipes used for supporting the carbureter became red hot and were bent by its weight, there were no signs of any injurious pressure

within the carbureter, the safety valve and trifling openings around the soldered joints permitting of

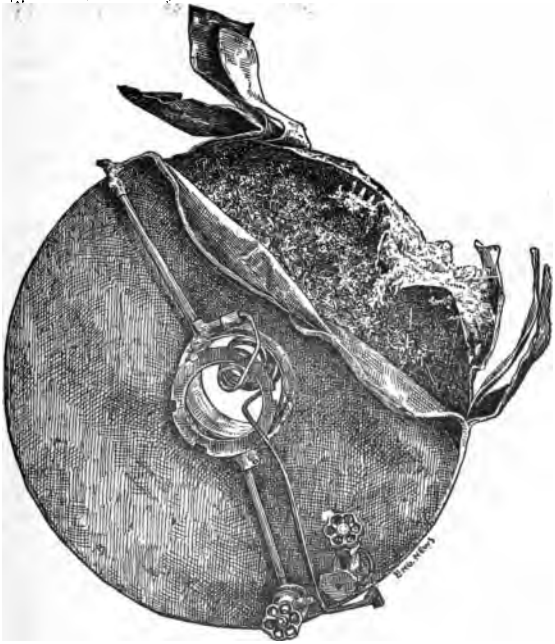


Fig. 35. New Carbureter Cut Open after being Subjected to Severe Fire Test.

escape of gas faster than it was generated, by a fire which was certainly very fierce. It is true that it

was as certainly not as fierce in its heating effect as would be a car on fire with a carbureter somewhere inside of it. It is possible, if not probable, that in such a fire a carbureter might pop open from pressure, especially if the pipe leading to the safety valve should chance to have closed by a blow, but the test seemed to conclusively demonstrate that it could in no case do this till long after all life in its vicinity had become extinct from other causes, nor would any such explosion be likely to do more than tear it open.

After the fire built had done its worst it was put out, and the carbureter cooled off and cut open to ascertain its interior condition. Fig. 35 shows the result as noted. The interior wicking was slightly burned on the surface, and on the corners quite a little charred, but it was substantially quite uninjured, and the interior was as white as when new.

Fig. 36 gives a view of another carbureter which, after being subjected to a like fire with a like result, was recharged with 3 galls. of gasoline, and placed under a 5,000-lb. steam hammer. It was first given two or three light blows "to see if the seams could be ruptured," the published accounts say, but this is not quite correct. It was done to first get the air out of the carbureter for fear that it would "pop like a paper bag," and in momentary forgetfulness of the bystanders that what it would do under a sudden blow was the very question to be decided. Whether it would have "popped" or not under such a very severe test is uncertain, but it is at least doubtful, since a final blow with the full force of the hammer caused no rupture nor considerable escape of gasoline. Fig. 37 shows a bottom view of the same carbureter.

These tests were made in April, 1890, in the presence of the editor of this journal. They were certainly an impressive exhibit of the toughness of the carbureters, and of their ability to withstand hard usage effectively both from fire and violence. The precise conclusions to be drawn from them we shall

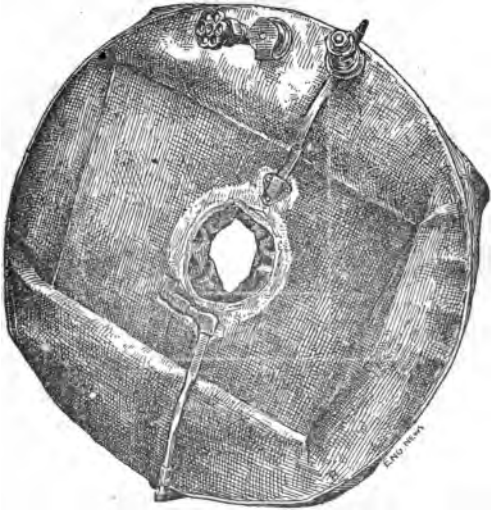


Fig. 36. View of New Carbureter after having been Subjected to Fire Test and thereafter Recharged and placed under a Steam Hammer.

consider later in discussing the question of safety. In the meantime we record the facts.

Some further tests of the effect of impact on the carbureter were made at Altoona, in June, 1890, of

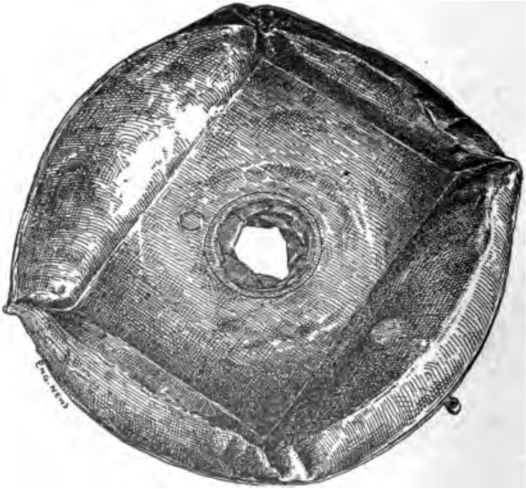


Fig. 37. Bottom View.

the nature indicated in Figs. 38, 39. They were thus described by the *Railroad Gazette*, whose editor was present at the tests:

> It will be remembered that in the "Thaxton's" wreck of July 2, 1839, on the Norfolk & Western, a car fitted with these carbureters was burned. The car was entirely consumed, but the carbureters taken from the wreck showed

no sign of explosion. They were distorted, and the soldered joints opened by the heat, but the lights were put out by the shock of the wreck; the fire did not start for an hour and a half later, and there is no evidence that the gasoline had any effect on it in any way.

Nevertheless, it has been suggested that there are two ways in which this system of lighting might cause disaster in case of a wreck. It has been said that a carbureter might be ruptured, and a car flooded with the volatile and inflammable gasoline; or that in case of a fire the rapid vaporization of the gasoline in the carbureter would cause an explosion. It was to show the probability of either of these events that the tests were made.

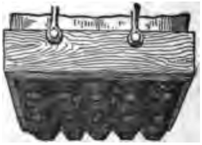
To show what might happen in case the carbureter was subjected to a heavy blow in a wreck, a new carbureter was placed on a solid backing of timbers, as shown in Fig. 26. The timber backing was, of course, far more substantial than that which the carbureter would have in its normal position on the top of a car, and the effect of a blow delivered upon it must be correspondingly more severe. Back of the timbers was a gas lamp connected with the carbureter. The carbureter was charged with 4 galls. of gasoline, and air was forced in by a hand pump to a pressure of 3 lbs. per sq. in. A drop, weighing 2,079 lbs., was arranged above the carbureter, and shod with timber, the end of which was serrated to represent somewhat the conditions which might be had in a wreck. The bottom of this drop is seen in Fig. 38.

This weight of 2,079 lbs. was dropped from a height of 33 ft. 4 ins., striking square on the carbureter and crushing it, as shown in Fig. 39. [This fall means an impact velocity of 30.6 miles per hour.—Ed.] The copper was not ruptured, but a small pipe inside the carbureter which extends into a pocket in the bottom of it, for the purpose of draining off gasoline left in charging, was driven through the metal. The seam where the top plate of the carbureter joins the side was opened for about ⅛ in.

in one place. Through these small openings a small amount of gasoline was squeezed out. It was estimated that perhaps half a pint escaped in this way; possibly, it may have been a pint. The iron case was then stripped off the carbureter, it was turned bottom side up, and the weight was again dropped upon it with the same fall, viz., 33 ft. 4 ins. In the first blow the wood had been entirely knocked off the bottom of the drop, so that in this case the carbureter was subjected to a blow from the iron ball alone. The timber backing was entirely demolished. Further openings were made in the soldered seams of the carbureter, but the copper was not ruptured. More gasoline was squeezed out; it was difficult to estimate how much, but it was not considered at all probable that the amount reached a quart after both blows. Of course, the carbureter was smashed flat, so that the volume inside was greatly reduced, and it was physically impossible that there should not have been some escape of gasoline. However, it must be remembered that the carbureter was overcharged with 4 galls. immediately before the tests were made; the service charge is 2 galls., while the first charging of a new carbureter is but 2½ galls. The amount of gasoline which escaped in this case was a good deal less than the excess of the charge over the usual first charge of a new carbureter. After seeing this test it is difficult to conceive circumstances under which any gasoline would be forced out of a carbureter from a blow in a wreck. The gas lamp which was burning back of the carbureter was extinguished instantly at the first blow.

A second fire test followed, similar to that already described.

These tests also were certainly most creditable. We shall consider what appears to us to be the proper conclusions to draw from them later. They so profoundly impressed our contemporary as to draw from it the somewhat sweeping conclusion: "So far as concerns the traveling public *there seems to be nothing left to be desired* [italics ours] in the matter of safety." It also expressed the conclusion that: "The two elements of danger which have been suggested are *entirely absent* in this system." While not prepared to go so far as our contemporary, which could hardly express more absolute confidence that every element of danger was eliminated if it called in the resources of several other languages besides our feeble English, we may say right here that these tests do show a closer approach to perfect security against certain dangers than we should have believed possible before the tests were made. Such a high degree of safety as to "leave nothing to be desired," cannot rationally be asked for, nor probably ever obtained from any system, but the danger (1) of explosion of a carbureter, and (2) tearing apart so as to scatter pieces of carbureter promiscuously around the interior of a car, seem remote. But, on the other hand, there are a variety of positions which might occur in a wreck which would try the carbureter more severely than the position of Fig. 38, a pile of 6 or 8 carbureters (it is proposed now to use 8 to 10 on a car for brilliant light) might give very different results from what one carbureter alone did, and the square carbureters now used (as described in our next issue) hold much more gasoline than the style illustrated and tested, while the falling weight, great as it was, inadequately represents both the W and the V^2 of a colliding train. While we endeavor to do these remarkable tests full justice, therefore, by admitting that they showed more resisting capacity than we had previously believed possible, we must not be understood to imply thereby that they indicate even sufficient, much less "entire," safety. They indicate sufficient safety if they show as much or more than can be otherwise obtained at about the same cost; otherwise they do not. Hence a final determination rests upon conditions yet to be determined.



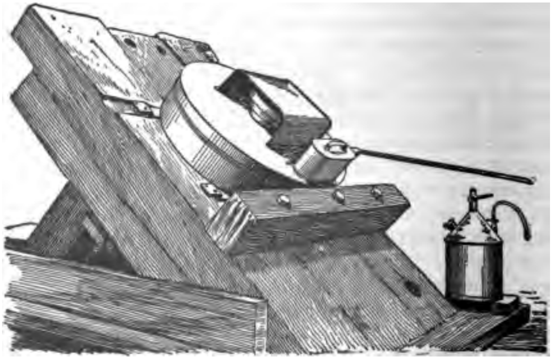


Fig. 38.

Since the preceding in its present form was in type an incident of some apparent moment in connection with this question has happened, as narrated in the reprint below. Pending the completion of this series of articles, and especially of that portion which relates to the question of the comparative safety of various systems of car lighting, it does not seem fitting for us to discuss the incident in any manner, nor can any one incident be decisive as to the question of absolute or comparative safety. But we deem it proper, and due to our readers, to reproduce without comment the newspaper record of the incident below, as a warning to be a little cautious what they do; and the curious may find by referring to sundry issues of this journal 12 to 15 months ago what was then our opinion as to the possibility of such incidents as

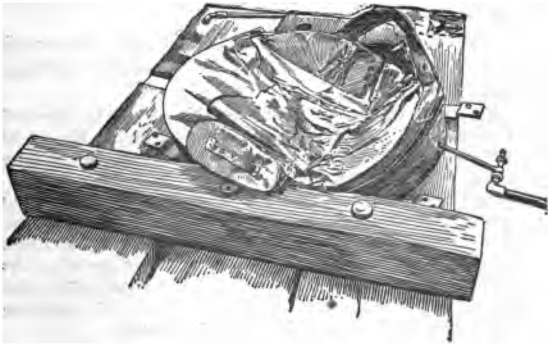


Fig. 39.

that which happened last week. At the present time, pending the completion of these articles, and of all the experiments on which they are based (some of which, of a supplementary nature, are even now in progress), we have no opinions, nor do we allow ourselves to form any, except that *caution* is necessary and that every incident of this nature should be justly and promptly weighed by those responsible for the safety of railway travel, and therefore should be promptly laid before them for their consideration.

The following is verbatim from the Savannah *Morning News* of May 6, minus the usual startling headlines:

Passenger coach No. 293 of train No. 3 of the Central Railroad, which left Savannah Monday night, May 4, at 8:10 o'clock, was totally destroyed by fire at the 20-mile post.

The fire was caused by the vapor arising from escaping gasoline coming into contact with the flame of a lantern. The car was illuminated by a gas made from the Frost dry carbureter system. The carbureter was placed on the roof of the car and filled with wicking. Air passes through from a storage reservoir on the bottom and picks up enough vapor to make a rich illuminating gas.

Through some unknown cause a sufficient amount of this vapor escaped into the lamp holder to extinguish the light, and Porter JOE SMITH undertook to remove [open ?] the lamp in order to relight it. As soon as he opened the holder the vapor escaped in large volumes and ran through the coach until it came into contact with the lantern, which stood at one end.

THE CAR FILLED WITH FLAMES.

Immediately there was a loud explosion, and flames shot upward through the car. The passengers, of whom there were quite a number, grabbed up their satchels and beat a hasty retreat through the other door, just in time to escape the flames. The porter stepped long enough to pull the bell rope, and received severe burns on the hands and arms.

Conductor CUBBEDGE, the moment he heard the bell ring, rushed from his cab and saw flames shooting up from the middle of his train. He realized that quick work had to be done, and lost no time in getting to the burning coach and cutting it off from the balance of the train. Had it not been for Conductor CUBBEDGE'S presence of mind the entire train would have been destroyed.

BURNED TO THE TRUCKS.

Nothing could be done to save the coach, and it burned rapidly. As soon as the destruction was complete the trucks were removed from the track and the forward part of the train was coupled to the sleepers, which had been in the rear of No. 298, and the journey to Atlanta was resumed. Although the delay had been of considerable duration, nearly all of the lost time was made up, and the train reached Atlanta yesterday morning only 15 minutes behind time.

The passengers had a narrow escape from being burned to death, and they were considerably excited over the affair. They all managed to save their effects, however, and all the loss sustained falls upon the railroad company. No. 298 was one of the Central's new coaches, and was worth about $4,800. There was no insurance. Porter SMITH was brought back to the city and given medical attention. His injuries are of a slight character, and he will be all right in about 10 days.

NOT AS SAFE AS WAS THOUGHT.

The gasoline gas system of illuminating has only been recently introduced on the Central, and but three coaches had been fitted up with it. It was thought to be one of the safest systems of car lighting in the world. Before adopting it the authorities of the road subjected it to the severest kind of test to find out whether there was any danger of it causing fire in case of a wreck.

Heavy weights were dropped on the carbureter, but it resisted successfully, and showed that there was no danger of fire from combustion. The Pennsylvania R. R. uses the system exclusively, and the Norfolk & Western and other large roads have also adopted it.

The Central now has but two cars using the light, and the authorities are making a thorough investigation into the causes of Monday night's disaster, to prevent any possible recurrence of a similar character. The Central's new sleepers do not burn any gasoline whatever, and there is not the slightest danger of any such accident occuring to them.

The statement that the Pennsylvania R. R. uses the system "exclusively" is not correct. Only a small percentage of its cars are equipped with it. It is true, however, that the system is in very extensive use on that road, as shown by the table published last week, and it is also true that most, if not all, of the new passenger cars added to its equipment in the last two years have been equipped with it.

Another account of this incident, differing in some details from the above, was published in the Atlanta *Constitution*, May 6, and that the precise nature of this (presumably) significant occurrence may be better understood, we reproduce that account also verbatim :

"Porter, there's gas in this car!" It was on the night passenger which left Savannah Monday evening for Atlanta. The train was about 15 miles this side of Savannah, running on a straight track, and at the rate of 35 miles an hour. It was nine o'clock. The passenger coach just ahead of the handsome new sleeper was crowded with men, women, and children. Suddenly the passengers in all parts of the car commenced sniffing. There was an odor of gas in the car, and as the porter came through it a New York drummer exclaimed as above.

One of the gasoline jets in the forward portion of the car had gone out. The porter climbed upon a stool to light it. He removed the chimney and then discovered that he had no matches. He reached down for his lantern and removed the lamp proper from the glass encasement in order to light the jet. [This is obviously impossible.—Ed.] The eyes of every one in the car were naturally upon him. He raised his torch. An explosion followed; the porter dropped, and a sheet of flame spread from one end of the car to the other, over the heads of the passengers. In an instant it seemed that every piece of wood in the car was a living flame. The men jumped for the bell rope, and in the excitement literally tore it to shreds. Men rushed to the car doors, and women screamed as the train sped on, carrying them in a prison of flames.

The train was quickly brought to a halt, but it seemed an eternity to those boxed within the encasement of fire. Before the last passenger got out flames were bursting through the car windows and licking the roof. Many escaped only with their lives, leaving their hand baggage to the flames.

But for the quickness and coolness of the crew the entire train would have been consumed. Conductor Beebe quickly uncoupled the burning car from the others. The front cars were pulled ahead by the engine and the rear sleeper forced back by the combined strength of the men aboard the train. Then the engine ran ahead to the next station, where another passenger coach and the wrecking crew were wired for. There was a delay of about five hours before the iron remnants of the burned coach could be removed.

Fortunately but one man was injured. He was Conductor Cubbage, who was not on duty, but happened to be coming up on the train. In his efforts to aid the passengers and remove the other cars one of his hands was badly burned and his face scorched.

We need hardly say that our columns stand wide open for any accounts or explanations of this incident tending to throw a different light upon it, or to explain how it is consistent with that perfect safety which has been claimed for the system, and which certain presumably competent persons have been so ready to certify to on evidence which to their minds seems to have been absolutely conclusive.

CHARGING THE CARBURETERS.

The arrangements for charging the carbureters are fully shown in Figs. 28, 29, 30, 31, already given, and in the following Figs., 40, 41. Fig. 40 shows the charging can, which is of 482 cu. ins. or 2.09 galls. capacity.

In charging it is stipulated first that there shall be at least 20 lbs. pressure in the air tank, and that the closet valve (just below the regulator, see Fig. 31, p. 428) shall be opened. The reason for this is that charging the carbureters is not allowed (at least by the more cautious roads) while the car is in service, and a certain amount of air pressure in the carbureters is necessary for the charging process. The regulator prevents more than 3¼ lbs. entering them, and the stipulation as to 20 lbs. pressure is merely to have enough margin to insure 3 lbs. speedily reaching the carbureters.

The charging can, Fig. 40, is then turned upside down and its nozzle placed in the filling valve (Fig. 30, and 18, Figs. 28, 29) where a slight turn of the can secures it in position, with a tight joint. A rubber

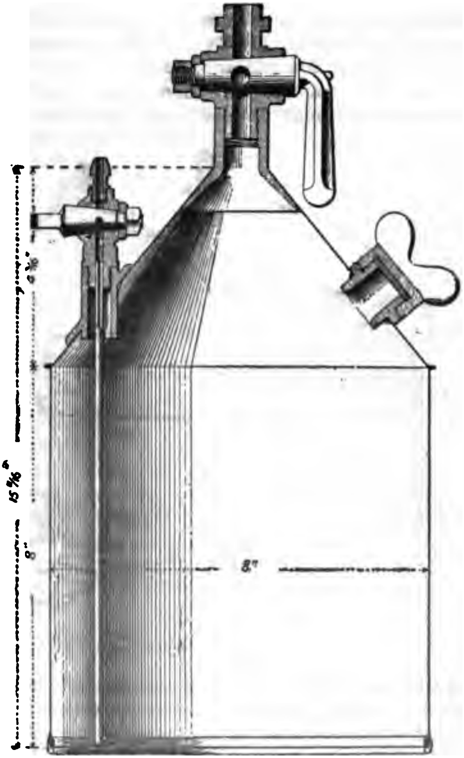


Fig. 40. Charging Can.

tube is then attached to the side nozzle of the can and to the "discharge valve" of the carbureter (Fig. 31, and 16, Fig. 29). All four cocks (two on the can, two on the carbureter) are then opened, and the gasoline flows through the discharge valve into the carbureter and spreads all over the *top* of the inner mass of wicking, the gasoline being permitted to flow out by the entrance of compressed air above it through the discharge valve and tube, this discharge valve connecting with a pipe leading to the inner

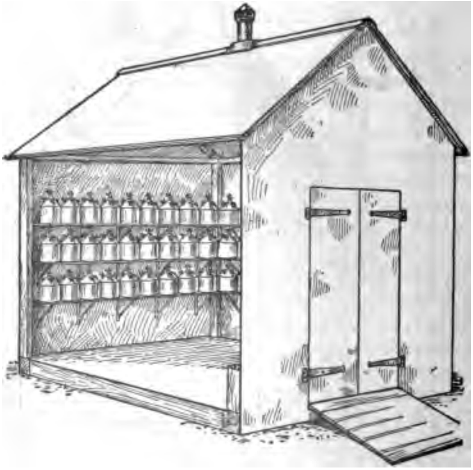


Fig. 41. Gasoline Cnarging-Can House.

part of the bottom of the carbureter, in a manner easily imagined, but not clearly shown in the drawings we engrave, to fulfill the following functions:

As soon as the wicking has absorbed all it can, it will be clear that free gasoline will begin to gather in the bottom of the carbureter, which runs toward this discharge pipe. To determine when this has taken place, the workman slips off the rubber tube from the discharge valve from time to time. Air will at first blow out, but finally, when the interior wicking is completely saturated, liquid gasoline, there being 3 pounds pressure in the interior. When this occurs all four of the cocks are at once closed, the two cocks on the can and the cocks on the carbureter; afterward the charging can is disconnected from the carbureter and the lid to the cockbox is closed.

"In a short time," say the instructions, "all the oil will be absorbed, and cannot be blown out except as a vapor or spray. Exhausted carbureters should take the full amount of oil for which they are rated without showing signs of overrating." It is obvious, however, that carbureters will usually be charged before they are fully exhausted, and hence that a small amount of unabsorbed gasoline is likely to be left in the bottom of the carbureter, which will be "overcharged." If so, this will be the first gasoline to be evaporated, and it will naturally soon be used up, leaving the interior "dry" as respects visible unabsorbed liquid. But to avoid leaving any liquid gasoline behind, as also to prevent any liquid gasoline escaping through the discharge valve of the cartbureter, the former regulations, as established on the Pennsylvania R. R. and still in force on that road, require that the charging can be kept in place until all gasoline has been discharged into the carbureter that will enter it, and without removal of the rubber tube to test the interior status of the carbureter, and that the surplus unabsorbed gasoline should then be returned to the charging can as follows:

Close, first, the can filling-cock, then, an instant after, the carbureter charging cock; then disconnect at the charging cock, leaving the rubber tube still on, and set the can down upright. Then open the filling cock of the can, which permits the interior air pressure to escape from it, and the interior pressure in the carbureter will then force back any free or liquid gasoline which may be in the carbureter into the can.

This process takes a little more time, but it avoids (1) the slight escape of oil or gas in testing at the discharge valve; (2) the possible small quantity of oil left between the two filling valves in shutting them off (there being no instructions to leave an interval of time between these operations), and (3) a second loss through the discharge valve in testing if a carbureter be overcharged, which latter will be only occasionally done. It was formerly required by the company's instructions, but is not now, that the charging shall only be done in the daytime, when lamps are not burning, and when the car is not in service or in a station. The regulation of these matters is now left for each railway to fix for itself.

The Pennsylvania road has its gasoline-charging cans filled at the refinery and shipped to them. The

Norfolk & Western buys 5 bbls. at a time and stores it in a large tank. From 15 to 20 % evaporates in a few weeks if kept in barrels, however tight, the gasoline being so volatile as to escape through the pores and cracks of the wood. The company's instructions recognize this point, stating that "Gasoline should be stored in iron barrels of 100 or more gallons' capacity or in filling cans. It cannot be kept profitably in wooden barrels." The Pennsylvania and other roads use a "gasoline charging-can house" like Fig. 41 for storing the gasoline for the use of yardmen in charging. The building is of sheet metal, with a wood or iron frame, as shown, 9 × 12 ft., and is said to cost only $200, holding 80 to 111 cans, which is said to suffice in service for 100 cars.

The company's instructions were formerly contained in an explanatory pamphlet of some length, but the company advises us that this has now been entirely dispensed with, and the instructions to employees for managing the plant are now all contained in two folding cards for the pocket, one for yardmen, giving instructions for charging, and one for trainmen, as to operating the lamps, it being very reasonably claimed that no one man is charged with both duties, and that the instructions were thus "boiled down considerably." In addition to the instruction as to routine details, which occupies only some 54 lines on both instruction cards together, the caution is added in large type to the filling instructions, "Use only 88° gasoline oil; test all oils for specific gravity before using," and, to the lighting instructions, "Keep the glass globes clean," and "Do not allow the lamps to smoke, and when passing through the car always look at them to see if they are burning properly."

The gasoline storehouse is placed at any convenient location in the yard convenient to the tracks. That at Altoona is about half a mile below the passenger station, near the old car shops. It is much like Fig. 41, but stands upon posts. A board floor is used, sheathed with sheet metal.

The interior capacity of the copper carbureter shell is 2,112 cu. ins., or 9.14 galls. The total quantity of gasoline in a fully charged carbureter is somewhat under 4 galls.; of which some 2 galls. only can be evaporated before the gas becomes too poor and recharging becomes necessary. In this latter condition, though there is really a great deal of gasoline in the wicking, it is all but imperceptible to

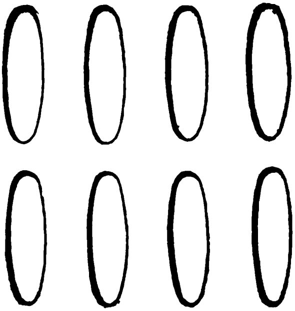


Fig. 42. Standard Perforations for Wicking, New Square Carbureter (full size).

any other sense than that of smell, and not very noticeable in that way. We learn of no evidence that the pores of the wicking fill up with extraneous matter and so degenerate materially, even after several years' service. Our impression is that carbureters will average in this respect at least 15 years' life, possibly more. We have seen samples of wicking from carbureters said to have seen several years' service, which were to all appearance good for many years' more service. Should the carbureter be charged by error with too heavy oil, it can be gradually expelled by lighter oil through the discharge valve, by running a few gallons of light oil through the carbureter.

It has recently been determined that it is desirable to enlarge the carbureter, and the carbureter now manufactured is 25 ins. square instead of round, increasing its interior capacity to about 2,413 cu. ins., or 28.6%. The square carbureter is the only one now manufactured or used by any one, we believe, except, of course, in stock already equipped. The effect of this is to increase the total absorbing capacity to nearly 5 galls., and the amount which can be burned out before recharging to 2.5 galls., or some 30%, thus affording that much longer service between chargings. Some additional absorbing capacity has also been obtained by increasing the amount of wicking used per square inch some 25%, thus making the mass of wicking solider. About 18¾ to 19 lbs. of wicking is now used in the square carbureter, against 12 lbs. formerly used in the round, an increase of 56 to 59 %, and the absorbing capacity should be increased in about the same proportion. It is proposed also to deepen the carbureter so as to obtain about double the former capacity.* More is claimed by the company in respect to time of service between rechargings than appears to be warranted by experiment. About 40 to 45 hours between chargings is the utmost that seems possible with the new lamps; and the new carbureter increases this to 56 to 63 hours, or, if deepened to double capacity, will give 80 to 90 hours.

The total length of the spiral passage in the wicking in the old circular carbureter is no less than 42⅓ ft., and in the new square carbureter about 60 ft. It goes without saying that there must be considerable resistance to the passage of air through such a long distance, and that the addition of more wicking will still further increase this resistance, but the additional capacity is considered to more than balance any disadvantage in this respect.

---

* In regard to the recent and proposed changes of the carbureter the company writes us: "A number of changes that have been made in connection with our car-lighting system of considerable importance, principally the reconstruction of the carbureter from circular to square. The circular carbureter gave from 55 to 60 hours' service, and the new square one will give about 125 hours, the principle being the same. We are also changing the construction of our inverted lamp at the suggestion of the Pullman Palace Car Co., and we have found by experimenting that it will increase the candle-power illumination about 20%. Therefore, instead of getting an average candle power illumination of 90 with the present lamp, by a slight alteration in its construction we will be able to get in the neighborhood of 120 c. p.

"Our light stands upon its own merits, and will supersede others in a very short time, owing entirely to its superiority in every conceivable sense. The Pullman company has now adopted it as its standard, and is equipping its cars very rapidly; in fact, we cannot get the material out fast enough for them. When it is taken into consideration that in one item of expense alone, that with our system of car lighting, the Pullman company will save not less than $200 000 per year by saving their carpets from oil drippings, this to them is one of its greatest recommendations."

MISCELLANEOUS NOTES.

We find there is considerable difference in the commercial gasolines, which are all supposed to be of about 88° B. In Baltimore, and, we judge, in other cities also, the Standard Oil Co. always supplies gasoline which is really of 91° B. gravity for 88°, and this 91° gasoline boils at 82° Fahr. under 3 lbs. pressure, which is almost exactly the point at which it should boil, according to the diagram given in Fig. 1 (issue of April 18, 1891), at atmospheric pressure. We are not as yet accurately informed as to the effect of 3 lbs. or 5 lbs. pressure on the boiling points of gasoline of various proofs, but shall be able to give it before conclusion of these articles.

The bursting pressure of the carbureter is about 60 lbs. per sq. in.; 30 lbs. will never break it, and the proof test is 20 lbs. The precautions against overpressure are (1) the regulator, (2) the safety valve, (3) with the Bowman regulator, that all air supply passes through a $\frac{1}{16}$ to $\frac{1}{32}$ in. hole (0.062 to 0.031 in.), the exact sizes used being 0.04 in. for 3 lamps (of the old style, burning about one-third as much gas per hour as the present style), 0.052 for 5 lamps, 0.072 for 10 lamps. It is to be noted that this passageway is not greatly larger than the by-pass aperture ($\frac{1}{32}$ in.), but there is considerably more difference in pressure in most cases beyond doubt. Still, the Bowman regulator has been found unreliable, and is not now used, and, in our judgment, in part because the by-pass regulates the air supply after the lamp and carbureter are once well warmed up, nearly or quite all the air which is used passing through the by-pass. The reasons for this conclusion will appear more fully later.*

Summing up the old round carbureter weights:

The wicking weighs	12	lbs.
The copper case complete weighs	18⅛	"
The interior meter parts weigh	21	"
The outer mantle, etc., complete, weighs	83¼	"
Total weight of empty carbureter and case	135	lbs.
The charge of galls. gasoline weighs	21¾	"

The P. R. R. standard tank, 10 ft. 3 in. long and 16 ins. diameter, is tested to 300 lbs. and charged ordinarily with air at 70 lbs. It has been found to run a car with freshly-charged carbureters about 8 hours, and with nearly empty carbureters 3½ to 5 hours. To see how this compares with the capacity of the brake pipes to supply air, a Westinghouse 8-in. pump, under ordinary working conditions, will about keep air flowing through a ¼-in. hole at 60 lbs. pressure.

The interior capacity of this tank is about 14 cu. ft., which, if charged with air to 65-68 lbs. pressure, will hold about 4⅜ times its volume of air at 18 lbs. pressure, or some 65 cu. ft. of air, or 13 cu. ft. per lamp with 5 lamps per car. According to these figures, therefore, each lamp when the carbureters are full should use about 1⅝ cu. ft. of air per hour, and when the carbureters are nearly empty 3.7 to 2.6 cu. ft. per hour. In Mr. Penniman's tests as recorded in Table III. (p. 392 of Engineering News of April 25), he consumed almost exactly the same amounts per lamp. Other records of the Pennsylvania R. R., however, indicated 2½ and 5 cu. ft. per lamp per hour of air consumption; but this, we infer, was for tests when the lamps had not been burning very long, and hence when the air consumption was larger than after long burning.

---

*The purpose of the by-pass is thus explained by the company:

When the carbureters are freshly charged, or when the air is very warm, there is a possibility of carrying too rich a gas down to the lamps. To obviate this difficulty a permanent cross connection is made between the air inlet to and outlet from the carbureter. In this cross connection is a diaphragm with a very small hole, so that a small amount of air is taken across to the gas as it comes out of the carbureter, diluting it a little, and thus preventing any possibility of too rich or too smoky a gas reaching the lamp.

It is estimated on the Pennsylvania R. R. that, on an average of the whole year, cars in service are lighted for 3 hours per day, 4½ in winter, and 1½ in summer. Cars on long runs, however, are lighted all night, so that there is much inequality between different cars. A car with 6 lamps of the new style of burner will burn about a quart an hour of gasoline, which is at the rate of 3.63 oz avoir. per lamp per hour, Mr. Penniman having found about 4 oz.*

In the new square carbureter, in which the holes for the wicking are punched a little closer than was formerly the custom, there is one oblong hole of 0.125 sq. in. area for each 0.370 sq. in. of area, as shown full scale in Fig. 42. This shows that a little over one-third of the total area of the "heads" (through which the wicking is drawn) is occupied by the wicking where it passes through them As the wicking is here very much compressed, the interior space between them is doubtless very completely filled by the wicking when fully saturated with gasoline, the fluid gasoline itself being of such bulk as to occupy about 45% of the interior space of the carbureter.

---

* The distinction between *fluid* ounces and *avoirdupois* ounces is to be kept in mind. There are 128 fluid oz. and only 87 avoir. oz. in a gallon of 88° B. gasoline.

In regard to some of the preceding statements as to the capacity of the carbureter and its hours of endurance, Dr. CHAS. B. DUDLEY, Chemist of the Pennsylvania Railroad, writes us as follows:

It is a mistake to say that only 2 galls. of the gasoline in in the carbureter can be burned out. In order to make this clear, we will say that we have several times on a car during test filled a carbureter full, namely, a little less than 4 galls., and burned it down, so that it would take from 3 to 3¼ galls. to recharge it to the same condition that it was when the test began. Apparently reliance was placed on Mr. PENNIMAN's test of 40 hours, burning 6 ozs. of gasoline per hour. There are some unexplained difficulties connected with that test, however, which we have not been willing to regard as satisfactory, and we are inclined to think that in this view the carbureter people coincide; not that Mr. PENNIMAN did not do fairly, but that the carbureter was not properly set up. The reason why the charging can holds only 2 galls. is because we want a certain margin. If the carbureter will hold from 3½ to 4 galls., and will burn down satisfactorily to a point where it leaves one gallon in the carbureter, we can then add 2 galls. of gasoline without any danger of overcharging the carbureter; in other words, with a 2-gall. charging can and ordinary conditions of service, there would always be a half-gallon of capacity under extreme conditions left as a margin against overcharging, and this we deem good practice, so that it is not correct to say that only 2 galls. can be burned out.

As to the arrangement of the smoke bell and endurance of lamp, we will say that we have recently had the plate in the smoke bell taken out of the lamps on car 418, and that the car has burned since that time from 80 to 90 hours with the inverted lamps, and without any difficulty. There is really no necessity for the plate in the smoke bell, as the carbureter people claim. The car has been in constant service, and the light is perfectly satisfactory, except that as the carbureter gets nearer exhaustion the amount of light is diminished. It will be necessary, therefore, if it is desired to express the actual state of the case, to modify the figures given as to the amount of time between chargings. Of course if the capacity of the can is to determine the amount of time between chargings, 40 to 50 hours is perhaps all we will get. On the other hand with larger carbureters, or with a change in the charging can, which has been under discussion for some time, considerably more time can be obtained.*

Dr. DUDLEY also says in another note:

"We find to our regret that the inverted lamps which we have in service, have the smoke bell as shown, but we regard this as a very serious mistake, and as soon as we can make the change, we hope this practice will be abandoned. We do not approve of it, and we are inclined to think that the carbureter people themselves are weakening in regard to their advocacy of it."

---

* The cone put into the smoke bell was not put in to slightly check the free escape of heated air and gas as stated in the article, but for the purpose of preventing the in-rush of air (which occurs when the brakes are suddenly applied) from putting out the light. It was found that the cone deflected the air currents away from the top of the lamp, and thus they did not result in pushing down the products of combustion on the flame and extinguishing it. Our first construction had no cone, and we would prefer this now, but the cone or some other device seems essential to prevent extinguishing the light, when the brakes are suddenly applied.

Dr. Dudley will hardly need any assurance from us, we trust, that it is desired "to express the actual state of the case," but he will pardon us for suggesting that the above corrections are a little confusing. In the first paragraph it is stated that it is deemed good practice to have only a 2-gall. charging can, in order to leave a certain margin against over-filling. In the next it is claimed that we should modify our statement, that 40 to 45 hours is the limit of service for the new lamps, because, with "larger carbureters or a change in the charging can, which has been under discussion for some time, considerably more time can be had," though if the capacity of the can is to determine the time between chargings "40 to 50 hours is perhaps all we will get," or substantially what we said.

As to how much gasoline can be burned out of a full carbureter before exhaustion, we are quite ready to believe that at times much more than 2 galls. may be burned out if a poor light will be accepted, and doubtless it depends a good deal upon how the lamp is being burned, whether to give much or little light, whether gas will cease to be supplied fast enough and rich enough to maintain the flame in *status quo*. Mr. Penniman's tests, as recorded in the beginning of these articles, were made to show the lamp at its best in regard to volume of light, being accompanied by photometric tests; and they showed that the lamp burned well for 42 hours, until a little less than 2 galls. had been burned and then quite suddenly began to flicker and fail. This shows conclusively that *for giving the full light of the lamp*, as tested by Mr. PENNIMAN, somewhat less than 2 galls. was the burning capacity of the carbureter, and, as that chances to be also about the capacity of the standard charging can, the inference is natural that it is about the *certain* endurance of the carbureter, though at times it may burn out considerably more. Of course, with the new square carbureter the burning capacity and proper size of charging can well be increased pro rata with the interior capacity.

As to whether Mr. PENNIMAN'S experimental plant was or was not properly set up to fairly represent P. R. R. practice, that is now being made the subject of further test, and we therefore can express no opinion on it. The plant was set up by the Frost company, and to their satisfaction, and certainly corresponded in all discoverable respects with *their plant, as they have been manufacturing it for a year or two past*, and furnishing it to railway companies generally, and for a considerable number of cars on the Pennsylvania road. As certainly, the experimental plant did not correspond in some minor details, which may have important effect, with P. R. R. practice as developed on that road, and as exclusively practiced two years ago, and for the most part since.

The disputed points of difference lie wholly in the arrangements for passage of the gases of combustion upward, which in the P. R. R. plant are quite free, but in the present plant, as constructed by the Railroad Lighting & Manufacturing Co., are considerably obstructed, with the double end of keeping downward drafts from affecting the lamp and of throwing more heat around the carbureter, so as to cause a freer vaporization of the gasoline.

[In resuming the publication of this series of articles, the last of which was published in our issue of May 23, we must, in justice to ourselves, state that the interruption in the publication has not been the fault of this journal. The tests described below on the Frost dry carbureter system were completed last April, and their description has been in type for many weeks. The Railroad Lighting & Manufacturing Co., the owners of the Frost dry carbureter system, requested us, in a letter dated May 5, to delay the publication of the tests until they could be supplemented with tests made on carbureters attached to a car in service. The arrangements for these service tests were soon thwarted, however, by the manufacturers, who insisted that their own engineer should take an active part in the conduct of the tests, a feature of which we could not approve, and which was not approved by one of the experts who was asked to conduct the tests. The Railroad Lighting & Manufacturing Co. has also refused to loan us apparatus for use in further tests proposed to be carried out at Stevens Institute Laboratory; and has withdrawn an invitation it had extended to have further experiments made at its own factory by Professor DENTON of Stevens Institute on behalf of this journal, as soon as the invitation was accepted.

As our attempts to secure further experimental data concerning the carbureter system are thus thwarted, we feel under no obligation to put off any longer the publication of the tests already made. We take this opportunity to acknowledge the courtesy of the carbureter manufacturers in furnishing us information and affording us every facility for tests and experiments upon their system up to the time when arrangements were in progress for a service test, as narrated above. We greatly regret that they have seen fit to change this policy; and in order that we may do them no injustice we submitted a proof both of the above statement and of the following article to them before publication, offering to publish their criticisms or objections to anything therein contained. Their reply is given at the close of this article.]

THE FUNCTIONAL ACTION OF THE FROST DRY CARBURETER PLANT.

To make clear to our readers the significance of the following experiments on the Frost dry carbureter system of lighting we will summarize briefly the essential features of the system, our previous articles having given a full description of the details.

In the Frost system of lighting, a quantity of gasoline is held in absorption by a mass of cotton wicking in the interior of a flat circular copper case called the carbureter. One of these is placed over each lamp on the roof of the car, as shown in Fig. 47. Quoting from the manufacturers' catalogue:

> In this system the light is produced by burning in the lamps a gas generated in the carbureters. The gas is simply air carrying a certain amount of gasoline vapor. The air is taken from the air-brake service. The gasoline is absorbed in wicking contained in the carbureters, and the object of the appliances is to bring these substances

together, vaporize the gasoline and thus produce the gas.

The carbureter is a round flat box with a hole in the center and having within it a spiral chamber about 40 ft. long, which spiral chamber is filled with cotton wicking. The air inlet to the carbureter is near the center hole; the outlet is near the edge The air which is to pass into the carbureter is taken through a small copper pipe, which is bent in the form of a conical spiral and placed in the flue of the carbureter directly above the lamp. The object of this spiral coil is to heat the air before it enters the carbureter by the combustion from the lamp, and in this way to furnish the heat that is necessary to vaporize the gasoline and generate the gas.

As a further means of furnishing heat to the carbureter it is surrounded with an air space, which communicates with the inside of the car, so that warm air from the car constantly passes around the outside of the carbureter and out through the ventilator.

When the carbureters are freshly charged, or when the air is very warm, there is a possibility of carrying too rich a gas down to the lamps; to obviate this difficulty a permanent cross connection is made between the air inlet to and the outlet from the carbureter. In this cross connection is a diaphragm with a very small hole, so that a small amount of air is taken across to the gas as it comes out of the carbureter, diluting it a little, and thus preventing any possibility of too rich or smoky a gas reaching the lamp.

The apparatus described is that first developed by the company, shown in Fig. 43. Since the above was published the manufacturers have substituted the lamp shown in Fig. 44, have done away with the copper coil for heating the air supply, and have obstructed the flue above the lamp so that a greater proportion of the heat from the lamp circulates around the carbureter. The Pennsylvania R. R. have substituted the lamp shown in Fig. 44 for the old style, but still retain the copper coil, and do not use the "deflector plate" seen just above the words "Smoke Bell" in Fig. 47. Thus, in the Pennsylvania system only the warm air from the roof of the car circulates around the carbureter; while in the system now furnished by carbureter manufacturers a considerable proportion of the hot air from the lamp flame passes around the carbureter, and of course heats it more or less.

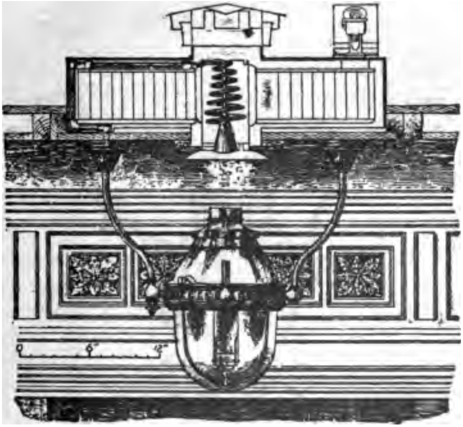


Fig. 43. "Excelsior" Lamp, Frost Carbureter System, as formerly used on the Pennsylvania R. R.

It is obvious that this latter system is the one in which the general public is chiefly interested. The points on which it desires information relate to the plant as it now is, not as it was two years or more ago, especially as the plant in its present shape is now in use on all the roads using the system at all on any considerable scale, except the Pennsylvania lines, and is the only one now manufactured or sold except on special order.

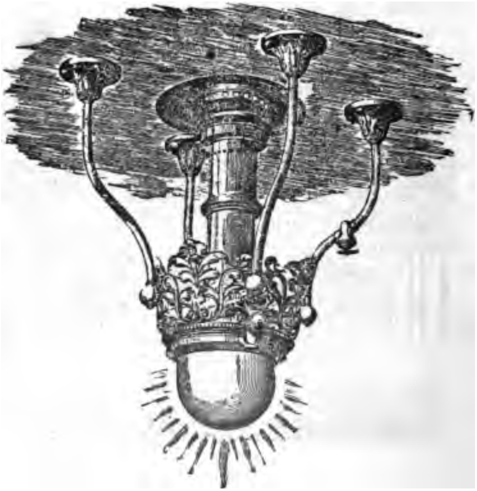


Fig. 44. Present Form of Lamp. Frost Carbureter System.

To what temperature is the gasoline in the interior of the carbureter raised in the system of gasoline lighting now furnished by the Railroad Lighting & Manufacturing Co.? The answer to this question is furnished by the accompanying Tables VII and VIII, and the diagrams, Figs. 45 and 46. Table VII and Fig. 45 show the results of a test made by the Railroad Lighting & Manufacturing Co. at their factory in Philadelphia on Feb. 17, 1891, and reported by them to this journal. Table VIII., and Fig. 46 show the results of a test made by Mr. W. B. D. PENNIMAN at the same place on April 13, 1891, the plant being set up by the manufacturers, and the test conducted to their satisfaction. Fig. 47 shows the position of the thermometers used in the tests.

The important facts which the above tests brought to light are, first, that the gasoline in some portions of the interior of the carbureter was *heated to the boiling point;* and, second, that for hours together *no air was used at all,* the gas supplied to the carbureter consisting of pure gasoline steam.

Is the working of the system in service the same, practically, as in the above recorded tests? If so then its working is totally different from that heretofore published and generally accepted. Instead of the carbureter being a chamber through which air passes, taking in up its passage a certain percentage of gasoline vapor, it is (at certain times at least an externally heated boiler in which gasoline is evaporated at a temperature of 119° Fahr. and a pressure of 3 lbs. per. sq. in. above atmospheric.

We greatly regret that no tests corresponding to those above have been made on a carbureter in place

TABLE VII.—TEMPERATURES IN DEGREES FAHR. IN AND ABOUT THE CARBURETER DURING A SEVEN-HOUR TEST OF THE FROST CARBURETER LIGHT.

[Record of a test made by the Railroad Lighting & Manufacturing Co. at their factory in Philadelphia, Pa., Feb. 17, 1891. From this table the diagram in Fig. 45 was constructed.]

N. B.—The position of the experimental carbureters, as shown in Fig. 48, and elsewhere described, is to be carefully noted. *It is disputed* whether this test represents sufficiently well the conditions of practice.

Time. P. M.	Air meter reading.	Cu. ft. air per hour.	THERMOMETER No. (For position see Fig. 47.)										Tank press., lbs.
			1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
2:35.	810	6.	74	74	74	71	70	73	71	72	73	71	70
2:45.	820	...	194	124	144	76	80	190	74	72	74	72	70
2:55	916	57.8	198	154	192	82	108	212	78	74	74	72	68
3:05.	019	55.8	230	182	212	90	110	220	80	78	78	75	65
3:15.	132	67.8	250	210	218	100	112	220	84	80	80	76	63
3:25.	205	43.8	258	214	220	104	114	220	86	82	82	76	61
3:35.	280	45.0	260	220	210	110	110	210	90	84	86	76	60
3:45.	305	9.0	260	226	224	116	110	210	92	86	90	76	58
4:15.	513	41.6	240	222	210	120	110	210	100	94	96	77	55
4:45.	610	19.4	240	222	210	122	120	210	108	100	102	77	53
5:15.	643	6.6	240	214	190	122	114	212	112	106	110	78	52
5:45.	651	1.6	244	211	200	126	130	210	116	110	110	77	51
6:15	602	9.8	280	240	210	130	122	200	120	114	114	77	51
6:45.	604	....	275	260	210	132	122	205	120	114	116	76	51
7:15.	604	....	250	260	190	122	120	190	120	118	118	76	51
7:45.	604	....	260	260	190	124	116	190	120	118	118	74	51
8:15.	604	.	290	260	200	126	118	190	120	118	118	72	50
8:45.	....	....	270	260	190	124	118	190	120	118	118	72	50
9:15.	....	....	240	260	180	124	120	190	120	118	118	72	50

Air supply was on full to the end, but consumption of air ceased at 6:15 P. M., when a negative reading of the air meter occurred because of a leak, as explained under Table VIII.

When the lights were turned out the air pipes were found filled with oil, two pints or more having been taken out. One-half pint ran out of the meter at the outlet.

About 6 P. M. the windows below and above the lamps were open, probably causing the condensation found in the pipes. The time of the first oil passing over was not noted. The delivery from regulator was at .9 lb. pressure. The air supply is for 5 lamps and carbureters, which were burning together. The air supply shown on the diagram (Fig. 45) is for one carbureter only, or 1-5 of that given in the above table.

TABLE VIII.—TEST OF THE TEMPERATURES IN AND ABOUT CARBURETERS, AND OF THE EFFECT OF SHUTTING OFF AIR SUPPLY, THROUGH BY-PASS ONLY, AND ALTOGETHER.

[Test made by W. B. D. PENNIMAN, April 13, 1891, on the experimental plant in the factory of the Railroad Lighting & Manufacturing Co.]

N. B.—Air supply given in this table is for one carbureter; in Table VII. for five carbureters in series.

Time, P. M.	Air meter reading.	Cu. ft. air per hour.	THERMOMETER NO. (For position see Fig. 47).									Tank press., lbs.
			1.	2.	4.	5.	6.	7.	8.	9.	10.	
1:15	350		76	76	68	68	70	70	68	70	82	53
1:30	405	22	164	138	75	136	150	78	70	72	82	47
1:45	435	12	174	172	72	142	260	80	74	80	84	44
2:00	469	13.6	172	172	84	146	260	86	76	82	84	41
2:15	473	1.6	182	176	90	150	262	90	80	86	81	37
2:30	485	4.8	186	184	96	150	262	94	84	88	86	34
3:00*	497	4.8	180	184	102	154	158	100	90	92	86	28
3:15	497	0	176	188	104	154	156	104	94	96	86	24
3:30*	†458	—15.6	184	188	104	154	162	106	98	98	86	....
3:45	458	0	174	188	106	154	156	98	100	100	86	....
4:00	458	0	154	204	110	150	250	110	102	102	86	....

*At 3:00 P. M. the by-pass was closed, compelling all air supply to pass around the coil within the carbureter through the wicking, if at all; and at 3:30 P. M. all air supply was cut off.

Pressure in Carbureters.—2.2 lbs. down to 3:15 P. M., and thereafter 1.4 lbs.

† The minus reading of 458 was due to the back pressure on meter, and the latter reversed its motion, the air or gas escaping at a leak which was afterward stopped.

on a car; and that the manufacturers, as noted above, have taken what seems to us the mistaken position that they will furnish no facilities for tests of this or any other feature of the carbureter plant by disinterested parties. This being the case, however, we can only lay before our readers the facts concerning the tests above recorded, leaving them to judge for themselves whether the position in which the carbureters were placed during the tests above reported was such as to heat the carbureters above what would frequently occur when they were in place on a car.

Fig. 48 is a cross-section of the large factory room in which the carbureters were placed. They were supported on two wooden scantlings, 3 × 4½ ins. in size, running lengthwise of the factory and suspended by rods from the ceiling. The carbureters were placed about 5 ft. apart on these scantlings.

The carbureter manufacturers objected to the publication of these tests, as already stated, giving their reasons as follows, in a letter dated May 5:

> The record was not gathered with a view of publishing the same, as the results were obtained in a closed room heated by steam, with the carbureters placed in a position in which they could not, under any circumstances, be placed in a car. It was only a factory or laboratory test made for certain information which we were desirous of obtaining, but not in any sense representing the condition of the system in actual service.

It is certainly true that the carbureter was not in the same position as on a car; but it is by no means certain that the position in which it was placed tended to heat it more than or as much as, it would be heated in service. Fig. 47 shows the position of a carbureter on the roof of a car. It will be seen that the outside air and wind have no contact with the carbureter, but touch only the non-conducting exterior mantle, and through that tend to chill only the top and side air passages, which Figs. 45 and 46 show to have in any case a moderate temperature, the heat being greatest under the carbureter

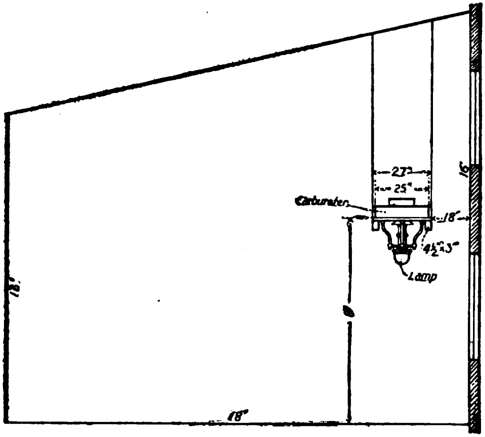


Fig. 48. Sketch of General Arrangement of Experimental Plant in the Factory of the Railroad Lighting & Manufacturing Co., with which the Records of Figs. 45 and 46 were Determined.

where the exterior air has no chance to have a cooling effect. Again, the interior of the clere story of a car is likely to be hotter than 75°-77° (which was the temperature of the room in which the tests recorded in Table VII were made), rather than cooler, in either winter or summer, in ordinary service.

The scantlings on which the carbureters stood cannot have collected nearly as much heated air beneath the carbureters as would the roof of a car. They were placed midway of the height of a large, open factory (see Fig. 48), on which the heat of combustion would have no sensible effect; and the thermometer record (therm. No. 10) shows that the lamp did not in fact have any sensible effect in increasing the surrounding temperature.

As we have already stated, the temperature of the carbureter will depend largely on the amount of heat from the lamp which circulates around it. Figs. 44 and 47 show the arrangement of air passages in the carbureters and lamps used in the above tests. It will be seen that the direct passage of air up the central flue is cut off by a plate or partition in the smokebell, through which are 14 holes ⅝ in. in diameter. The total area for the passage of hot air up the central flue is therefore 4.30 sq. ins. On some of the lamps in use a "damper" is provided, by which even these 14 holes can be all but closed, leaving only an 0-shaped opening ⅜ in. high at the side of each hole, or only about 0.48 sq. in. in all, or about 1-10 of the full opening. When this damper is closed, therefore, nearly all the gases of combustion are compelled to circulate around the carbureter by entering through the annular opening at the side of the smokebell.

Now, neither in the tests made by Mr. PENNIMAN nor in those made by the manufacturers themselves reported above, were the dampers attached or in use. It seems thus plain enough that on cars having the damper a *larger* proportion of the products of combustion from the lamp may be circulated around the carbureter than was the case in the above reported tests.

In justice to the Pennsylvania R. R. Co. we should state that the description just given does not apply to the lamp and carbureter now in use on their lines. Such of the new-style inverted lamps as are in use on the Pennsylvania lines have no damper; and orders have been issued to remove the perforated plate in the smokebell entirely, leaving a free passage for the hot products of combustion up the central flue, obstructed only by the cone and heating coil shown in Fig. 43.

But the facts brought out in the above experiments are not the only ones which have developed tending to show that the method of operation of this system of lighting may at times be entirely different from what has been generally supposed.

At our request the manufacturers some months ago made experiments on the standard by-pass. To make clear the significance of the results obtained a brief explanation of the by-pass is necessary.

The accompanying sketch (Fig. 49) shows a half-section of the carbureter through the air passages. According to the heretofore announced and accepted theory of the plant, air enters at the "air inlet," passes along the spiral passageway 42½ ft. in length, and finally escapes at the "gas outlet" charged with a considerable percentage of gasoline vapor. But as it issues from the gas outlet it sometimes has too large a percentage of gasoline vapor, so a pipe is led from the "air inlet" to the "gas outlet," and a very small hole or "by-pass" is bored through a diaphragm in the end of this pipe. The capacity of this is claimed to be such that only about 10% of the total air supply passes through it.

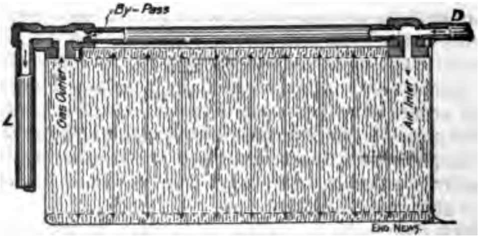


Fig. 49. Passages for Air Through and Around Carbureter.

This is the theory; let us examine it a little. The air enters the pipe *P* from the deck air pipe at 3 lbs. pressure.

By many different experiments the volume of mixed air and gasoline vapor consumed by the lamp has been determined to be 6 to 8 cu. ft. per hour. In order to reach the pipe *L* leading to the lamp, the air supply may either pass through the by-pass orifice or through the carbureter. It is claimed to pass through both. Evidently the volume which will pass through either will depend on the resistance which it offers.

At our request the manufacturers made tests on the capacity of the standard by-pass to transmit air at various pressures. It was found that 78 cu. ft. of air per hour was passed at 3 lbs. pressure and 47 cu. ft. per hour under 1 lb. pressure.

These two quantities are in almost exactly the ratio which theory calls for, of $\sqrt{1}$ to $\sqrt{3}$, or of 1.00 to 1.732; and if we assume that the discharges through the by-pass will continue to vary as the square root of the head, as theory requires and as we may justly infer, we shall have the following discharges of air through the by-pass under various pressures:

Pressure in—			Discharge in cubic feet air per hour—	
Ounces or pounds.	Inches of water.	Ratio of air discharged.	Observed.	Computed.
¼ oz.	0.43	0.1250	.	5.87
1 oz.	1.74	0.2500	....	11.75
4 oz. = ¼ lb.	6.95	0.5000	....	23.50
1 lb.	27.8	1.0000	47.0	47.00
2 lbs.	55 6	1.4142	....	66.47
3 lbs.	83.3	1.7321	78.0	81.40

So much for the capacity of the by-pass. Now, how much air will pass through the charged carbureter at these pressures? On this point, unfortunately, experimental data are wanting. As stated above, we endeavored to have tests made on this point by Prof. Denton, but our efforts were thwarted by the refusal of the manufacturers to loan a carbureter for use in the test. This being the case, we can only present the facts which show that there is very considerable resistance to the passage of air through the carbureter and leave our readers to judge for themselves how great this resistance is.

The spiral passageway through the carbureter is about 60 ft. in length in the new square form of carbureter, and is filled with wicking as solidly as it can be drawn in. The wicking is then saturated with gasoline. The total interior volume of the carbureter is 2,413 cu. ins. The maximum charge of gasoline is about 5 galls., or 1,155 cu. ins. About 19 lbs. of cotton wicking is used in each carbureter, and this is drawn in flat strips across the spiral passageway at intervals of ½ in. for the whole length of 60 ft. It seems certain that this must cause great resistance to the passage of air through the carbureter.

The makers of the carbureters have stated that a person with strong lungs can occasionally blow through a dry carbureter. Whether this could be done when the carbureter was charged we do not know. A strong man can exert about 3 lbs. pressure with his lungs.

But referring to the above table it will be seen that all the air which the lamp uses, from 1½ to 5 cu. ft. per hour, will pass through the by-pass alone with a pressure of much less than ¼ oz., or less than one-third of an inch water pressure. Thus, if only 10% of the air supply is to pass through the by-pass, as the manufacturers claim, the resistance to the passage of air through the carbureter must be exceedingly small. The evidence tending to show that this resistance is not small we have already given.

But if the air does not pass through the carbureter or passes through only in small quantity, how does the gasoline vapor reach the lamp? The results of the experiments reported in the tables and diagrams above enable an answer to this question to be made with a considerable degree of certainty.

In any carbureter, before the lamps are lighted, the voids of the interior are filled with air at 3 lbs. pressure, at a temperature of 70° to 80° F., which becomes richly charged with gasoline. The gasoline, being very volatile, will charge the air in the deck pipe as well as in the carbureter, for it is to be always remembered that gasoline is not a simple fluid like water, every atom of which has a common boiling point, but a compound fluid, some parts of which have a lower and others a higher boiling point than the mean; besides which, gasoline, like water (only with far greater ease), vaporizes or evaporates at temperatures far below the boiling point. It is the most volatile of liquids with the exception of ether, carbon bisulphide, bromine and one or two rare chemicals.

Opening the needle valve insures a sufficient supply of gas to light the lamps and burn a few minutes by mere expansion. It will also be seen shortly that there will probably be some little condensed fluid gasoline in the air pipes to carburate the air. After lighting, the temperature of the central flue rapidly rises (see line 6, Figs. 45, 46) to 150°-200°. The temperature under the carbureter also (line 3, Fig. 45, lines 1, 4, Fig. 46) rises rapidly to nearly the same point near the center, rising at the top and sides lines 4, 5) much less rapidly.

The carbureter absorbs heat from the current of warm air which circulates around it, and the gasoline inside is vaporized and flows out of both the "air inlet" and the "gas outlet" and thence down to the lamp, together with such air as is needed to make up any deficiency in volume.

To appreciate how small an amount of heat is needed to vaporize all the gasoline which the lamp burns, we must remember in the first place that gasoline is very easily vaporized or condensed, the heat absorbed in vaporization or given off in condensation, being only about one-quarter as much as in the case of water, or 250° to 300° F. On the other hand, gasoline is a somewhat better fuel than coal, being able, pound for pound, to evaporate at least a third more water. Now, the theoretical evaporation of good coal is about 15 lbs. of water per pound of coal = about 60 lbs. of gasoline per pound of coal = perhaps 80 lbs. of gasoline evaporated per pound of gasoline burned. Therefore only 1% to 2% of the heat generated by the flame of the lamp needs to enter the carbureter to keep the lamp continuously supplied with the vapor of gasoline, the amount of heat thus absorbed being the same whether the gasoline be merely vaporized or heated to the boiling temperature. To make the case still more plain, the amount of gasoline burned per hour being about 6 fluid oz. or 4 oz. avoir., the amount of heat required to vaporize it is but little more than would be needed to convert into steam 1 oz. per hour of water, or $\frac{1}{16}$ of a pint.

Evidently this is a very small amount of heat; and if even a small part of the heat from the lamp is circulated around the carbureter, it may certainly be expected that the gasoline vapor will be generated faster than the lamp burns it.

But when this occurs—when the heat which the carbureter absorbs *per hour*, either from the lamp or from the warm air in top of the car, is greater than that needed to evaporate *one-sixteenth of a pint of water*—then the surplus of gasoline vapor will push its way back into the air pipe on the roof of the car. There are 8 to 10 ft. per carbureter of this air pipe, made of thin copper, ⅛ in. in diameter, and exposed to the outside air. Under ordinary circumstances this forms an efficient *condenser*, and in it the gasoline vapor collects in a fluid form. This actually occurred in the experiments above described. (See Table VII.)

But with a hot summer sun shining on the car roof, the copper deck pipe will be a very poor condenser, and the heat of the surplus gasoline vaporized will be greater. Hence there will be no resource for the gasoline steam in summer except to raise the pressure, open the (5 lb.) safety valve and blow through; and if the reasoning so far has been correct, this must take place. It does take place. A considerable loss of gasoline in summer has been observed—just how much we have not been able to ascertain, but enough to lead to experimental efforts to use a heavier oil in summer. It has been ascribed to the direct effect of the sun's heat, and may be in part due to this, but it is more likely to be chiefly due to the cause just suggested.

There are other observed facts, too, which prove the correctness of the explanation of the working of the carbureter system. We will take space to note a few.

In each of the tests reported in Tables VII and

VIII the lamp burned for hours together without any

TABLE VI.—ENDURANCE TEST OF CARBURETERS ON CAR NO. 985, PENNA. R. R.

Day.	Date April, 1890.	Time of lighting.	Temperature.		Time of turning off.	Temperature.		Number of hours burned per day.	Total hours burned.
			Outside of car.	Inside of car.		Outside of car.	Inside of car.		
Tues...	15	5 P.M.	54°	51°	10 P.M.	44°	56°	5	5
Wed...	16	11 A.M.			5 "				
		6 P.M.	66	60	11 "	39	44	10	15
Thurs..	17	11 "	66	68	9 "	48	64	10	25
Friday	18	11 "	62	66	8 "	36	62	9	34
Satur..	19	11 "	63	59	9 "	42	61	10	44
Sun....	20	11 "	64	68	9 "	47	67	10	54
Mon..	21	11 "	69	66	9 "	56	73	10	64
Tues...	22	11 "	70	69	9 "	57	69	10	74
Wed...	23	11 "	78	68	9 "	58	70	10	84
Thurs..	24	11 "	58	62	9 "	58	69	10	94
Friday	25	11 "	47	51	9 "	51	66	10	104*
Satur..	26	11 A.M.	44	48	2 "	46	53		
		3.30 P.M.	44	48	6 "	46	53		
		6 "	44	48	10.30 "	46	53	10	114†
Sun....	27	11 "	56	52	9 "	44	57	10	124‡
Mon...	28	11 "	70	66	9 "	52	70	10	134§

* The Excelsior burners show signs of weakness.

† Two Excelsior lamps gave out.

‡ Continued weakness of "Excelsior" lamp. Inverted lamp is also weak.

§ A very fair light from both lights.

NOTE.—This car was equipped with five standard lamps with Excelsior burners and one "inverted" lamp with the Siemens (present form of) burner.

air being used at all, which could only have occurred through the gasoline being evaporated faster than it was used by the lamp. In another test made by Mr. PENNIMAN, at Baltimore, in which the plant was set up by the inventor of the carbureter system, the amount of air consumed per hour fell as low as ⅛ cu. ft.

Again, in this test 11 oz. of gasoline, or $\frac{1}{18}$ the total amount used, was blown off at the safety valve. In the test made by the carbureter manufacturers the air pipe was cool enough to act as a condenser (see Table VII), and about a quart of gasoline collected in it. This fact alone disposes of the manufacturers' objections that the room in which this test was made was too hot to make the test a fair one.

Still another fact having a bearing on this question was developed in a test of the endurance of the carbureter with different forms of lamp, made by Mr. JOHN D. BOWMAN, Assistant Mechanical Engineer, Pennsylvania R. R. The details of the test are given in Table VI. Mr. BOWMAN says:

> With the Excelsior burner it takes from 20 to 30 minutes in lighting the lamp in a cold car, with the carbureter nearly exhausted, before the carbureter is sufficiently warmed to raise the flame to its normal burning height; when the car is warmed up to about 70° F. and ready for occupancy by passengers, the carbureter will be sufficiently warmed in about 10 minutes with a freshly charged carbureter. However, the flame as soon as lighted can be turned to its normal height, but in 3 or 4 minutes should be turned down a little to prevent smoking.
>
> In lighting up the lamps in a car the flame is at first only turned from ½ in. to ¾ in. high, and then as the carbureters become warmed up they creep up to about

1¾ ins. or 2 ins., which is the proper height, without further attention from the trainmen.

With the inverted burner, however, we have observed that the flame when first lighted can be turned at once to its normal burning height (just covering the perforated flame plate). Its tendency is, as the carbureter becomes warmed, to grow whiter rather than to creep up; this is due, we think, to the regenerative principle upon which this burner is constructed.

The explanation of this is that the Excelsior lamp, shown in Fig. 43, heats the carbureter much less than the present inverted type of lamp, Fig. 44, as already explained. Hence there is more condensation in the air pipes with the inverted lamp, and the air which passes to the lamp when it is first lighted is more highly charged with gasoline vapor.

We greatly regret that the manufacturers of the carbureter system have seen fit to withdraw from their promise to furnish us all necessary facilities for making a complete investigation of their system of lighting, thereby blocking the further experiments which had been arranged for. This being the case, however, we have had no choice but to lay the results thus far obtained before our readers, pointing out as plainly as possible their significance and importance. We have briefly summed up the matter in our editorial columns.

Note.—As there has been some conflicting evidence in previous articles of this series concerning the length of time which a carbureter will furnish gas with one filling, a test of this question was made under the immediate charge of Mr. JOHN D. BOWMAN, Assistant Mechanical Engineer, Pennsylvania

R. R. The present writer examined the car during this test, and can testify that the whole interior was brilliantly illuminated, though what the actual candle power was it would be impossible to guess, and it was not determined. It will be seen, however, that one of the lamps was of the present form (perhaps with somewhat smaller passages) and yet gave somewhat more hours of service then the old Excelsior lamp, viz.: 124 hours against 104, whereas the lamp as tested by Mr. PENNIMAN gave only 42 hours' light. There may have been some difference of charging, but allowing 3 galls. to have been burned out in one case and 2 galls. in the other there is the contrast of only 20 hours of light per gallon against 40 hours. On the other hand, other Pennsylvania records show "a quart per hour" for 6 lamps, or 24 hours' service per gallon; but after making all allowances, the contrast indicates that there is a real difference of function, the original Pennsylvania plant burning the oil less rapidly, giving less light and not heating the carbureter so hot. We may note also that a large variety of inverted burners are offered by the carbureter manufacturers, and are claimed to give different amounts of light. A correction should also be made for the gasoline lost by blowing off in the photometric tests, reported in our issue of April 25.

LETTER FROM THE MANUFACTURERS OF THE FROST CARBURETER SYSTEM.

PHILADELPHIA, Pa., July 27, 1891.

ENGINEERING NEWS, TRIBUNE BUILDING, New York City:

GENTLEMEN: Replying to yours of 21st inst. We have read the proofs submitted and regret your decision to publish with such haste the articles, and are astonished to learn that you are not willing to wait until the practical tests are made in service. It is intended that this shall be done as soon as practicable, and we think you are making a great mistake in anticipating the same by publishing the crude information with which you have been furnished from laboratory tests.

We desire to place ourselves on record as objecting to your articles, and when the time comes will answer them in the proper way. Actual experience of cars in service for years past does not sustain the serious defects your articles would convey to your readers.

Again regretting that you have seen fit to use such haste in this matter, without being properly informed on the subject, we remain, yours very truly,

THE RAILROAD LIGHTING AND MANUFACTURING CO.

The Pintsch Compressed Oil Gas System.

The Pintsch oil gas system of car lighting uses a rich gas made from crude petroleum as the illuminant. The gas is made at central stations and compressed in receivers, from which it is piped into cylindrical steel tanks placed underneath the car. From these it is drawn as needed for use in the car lamps. The principal elements of the system are as follows:

1. A fixed gas plant for generating the gas, of the same general nature as any other gas works, but using crude petroleum instead of coal as the source of the gas. This is done for the double reason that the oil gas is much richer in illuminating properties than coal gas, and does not lose so much of its illuminating power by compression.

2. A compressor which forces the gas after it is

generated into storage tanks or receivers at a pressure of 150 lbs. per sq. in. or more.

3. A system of fixed pipes for conveying the compressed gas from the storage tanks to various points about the yard convenient for supplying gas to cars; or, in lieu thereof, large tank cars by which the gas can be transported in quantities sufficient for 5 to 10 days' supply to points distant from the gas works.

4. One or more steel tanks beneath each car, for holding a supply of compressed gas, sufficient for two to six days' burning.

5. A "regulator" or reducing valve in immediate connection with the car tanks, by which the gas is reduced to the constant and very low pressure (½ in. to 1 in. of water) which is required for burning gas to advantage, and this under all conditions of varying tank pressure, temperatures, dust and dirt in the air, concussions of service, etc.

6. An ordinary system of gas-piping and burners, modified only in this respect—that to make such a rich gas burn to the best advantage it is necessary to burn it on the regenerative principle, *i. e.*, heat it before burning. We will briefly describe the construction of each of these parts of the plant.

THE GAS MAKING AND STORING PLANT.

A very good description of this, as established at Glasgow, Scotland, to supply the Caledonian Ry., is given in a recent paper read before the Institution of Civil Engineers by GILBERT MACINTYRE HUNTER, Assoc. M. Inst. C. E. We quote from it as follows:

> The retorts (Figs. 50, 51 and 52) are D-shaped cast iron tubes, 5 ft. 10 ins. long and 10 ins. wide, placed one above another, the lower one resting its whole length upon a

firebrick sole. The flame from the furnace passes round both sides of the lower tube, over the top, and there engages with the upper tube, finally reaching the flue or combustion chamber. Thus the flame plays directly upon all parts of the tubes, not unduly heating some parts and others partially. The flues are built of ordinary firebricks. Both ends of the tubes are fitted with mouthpieces or covers, admitting of thorough cleaning.

The oil is pumped from barrels into a 15-gall. cistern on the top of the retort bench, which thus maintains a constant head and a steady flow. It enters the upper retort, Fig. 51, in a thin continuous stream from a micrometer cock, through a siphon pipe, and falls upon an iron tray on the bottom of the retort. This prevents the cold stream of oil coming in direct contact with the hot retort and thus reducing its temperature. Here it is partially vaporized, and, passing through the tube, descends to the lower tube, where it encounters a higher temperature, rendering it permanent or "fixed." The object of this is to insure that every portion of the vaporized oil shall be acted upon by the highest temperature, without undue exposure to the heated surface of the retort. As the gas leaves the retort it is largely mixed with tarry and other vapors, which give it the appearance of smoke of a more or less dense nature, in proportion to the quantity of such matters present.

[The author then describes the process of purifying the gas, consisting first in separating the tar by passing the gas in thin streams through water, and then removing sulphur compounds and carbonic acid by passing it through slaked lime and sawdust spread 2 ins. deep in perforated plates.]

At night the main valve is shut, the dampers are closed and the covers over the tar pit are removed, to allow the gas in the pipe to escape; the manhole covers are also removed and the tar and pitchy matter drawn off. The mouthpieces are next taken off, the retorts cleaned out, and the covers replaced; the fires are drawn, and afterward banked for next morning. The fires are kindled with coal and dross; thereafter they are wholly maintained with coke, which gives much better results than coal. After they have been kindled for about an hour and a half the oil is turned on. The proper heat has not been obtained yet; but, owing to the de mands on the work, longer time cannot be spared, so that the yield of gas per gallon of oil is comparatively small for the first hour or so. When the retorts are irregularly heated there is a large increase in the quantity of tar; while, if they are overheated, the distillation is attended with a separation of carbon in the form of soot, and if insufficiently there is deposited in the retort a carbonaceous substance resembing cloke, in addition to an abundant production of tar. The best temperature is a bright cherry red heat, verging on white; then there is only a small quantity of carbon or soot.

A high illuminating gas can be produced when the yield is small, and conversely, with a high quantitative yield, the light-giving qualities of the gas will be diminished. A fairly good yield, which can be obtained in every-day practice, is 70 to 85 cu. ft. per gall. of 50 to 60 c. p. gas. Mr. J. B. MacArthur has shown that a yield of 120 cu. ft. per gall. was only equal to 40 candles, and that when the yield reached 158 cu. ft. the candle power was only from 20 to 25.

No. 1 bench was worked continuously for 14 weeks in the winter of 1887-8, during which time 8,294 galls. of oil were distilled, producing an average of 80.76 cu. ft. per gall. During the year 1886 the average yield was 72 cu. ft. of gas per gall. of oil; and in 1887 this was raised to 81.22 cu. ft. Approximately it takes about 5 tons of coke, 4½ tons of dross and 10 cwt. of coal to make 100,000 cu. ft. of gas, or about 0.22 lbs. of fuel per cu. ft. The cost of making the gas, including oil, fuel, wages, repairs, etc., is 6s. 7.24d. ($1.58) per 1,000 cu. ft.

In another paper read before the Institution of Civil Engineers recently, Mr. ARTHUR AYRES described the gas works on the Pintsch system erected by the Trinity House Corporation at Blackwall, England, for the supply of buoys and beacons. He states that in operating the plant there should be a water pressure of 5 or 6 ins. in the retorts, gradually diminishing to about 1½ ins. in the holder. The gas is made at the rate of about 210 cu. ft. per hour per pair of retorts. The quality of the gas depends more on the temperature at which it is distilled than upon the quality of the oil. The gas shows from 40 to 50 c. p. when burned in a London standard Argand burner with a consumption of 5 cu. ft. per hour at a water pressure of 0.5 in. The quantity of gas produced from one gallon of oil is 70 to 90 cu. ft. The price varies from about 5s. 6d. to 16s. ($1.32 to $3.84) per 1,000 cu. ft. Where the demand is great, the cost of production is correspondingly low.

From Mr. AYRES' paper we condense the following table, giving particulars of the Pintsch Gas Works on several British railways:

Name of Company.	Cost of works.	No. of works.	No. of retorts.	Yield p. retort p. hour, cu. ft.	Cu. ft. gas per gal. of oil.
Caledonian...	$19,420	1	8	480 to 600	81.17
Metropolitan	38,800	2	16	150 to 175	77.00
Midland......	20,127	1	6	——	74.16
Glasgow & S. Western....	16,975	—	5	——	76.25
London & S. Western....	30,264	2	20	507	81.00
Great East'n.	33,465	1	12	134.5	72.00

		N't cst p. 1,000 c. f.			
Name of Company.	Annual output, thousands of cu. ft.	Exclusive of interest and repairs.	Adding interest and depreciation at 10 %	No. of cars equipped.	Gas consumed per burner per hour, cu. ft.
Caledonian...	1,892	$1.58	$2.61	603	0.74
Metropolitan	8,500	1.44	1.89	310	1.035
Midland......	3,948	1.68	2.19	182	0.75
Glasgow & S. Western....	1,316	1.57	1.69	440	——
London & S. Western....	2,697	1.37	2.83	890	0.70
Great East'n.	3,460	1.48	2.44	611	0.75

NOTE.—The gas is measured for the purposes of the above table as it passes into the holder, before compression. The quantity of gas available for lighting is probably 10% less.

The loss of candle-power of oil gas made from crude petroleum when compressed was found to be as follows in experiments made some years ago by JULIUS PINTSCH:

5 atmospheres	2.4%
10 "	7.4%
15 "	16.3%
20 "	21.5%

In compressing the gas for use on cars at the Glasgow works, as described by Mr. HUNTER, a compound compressor is used and the gas is compressed to about 60 lbs. in the first cylinder and 150 to 180 lbs. in the second cylinder. The compressing cylinders are kept cool by a jet of water running around them. In going from the gasholder to the compressing pumps the gas passes through a freezing cylinder which converts to ice any moisture which the gas may have taken up in passing through the washer and holder. It also economizes the power necessary for compression and reduces the heat of the pump cylinders.

The compressed gas is stored in steel tanks of any convenient size. Pipes lead from the bottom of each to a receiving drum to draw off the liquefied hydrocarbon, which collects in the bottom at the rate of about 1 gall. for each 1,000 cu. ft. of gas. Mr. HUNTER says:

> On an average the gas loses about 5 c. p. by compression and deposit of the hydro-carbon. The hydro-carbon gives off an inflammable vapor at a temperature of less than 45° Fahr. It is, accordingly, rather a dangerous substance to work with, and is generally drawn off from the drum into smaller ones for transmission to manufacturing chemists on a dull, moist day.

The process, as above described, is substantially that used in this country in the manufacture of Pintsch gas. The compressors used however, are not compounded. The accompanying engraving, Fig. 53, is reproduced from a photograph of the compressor at the Pintsch gas works in Boston.

The following are official figures from a gas-works on one of the leading railways using the Pintsch system in this country. Between July 1, 1890, and Jan. 31, 1891, this works made 1,483,782 cu. ft. of gas at an average total cost per 1,000 ft. when placed in the car tanks of $4.206. This was divided as follows:

Labor on works	$.94
Labor, car filling	.452
Supplies and repairs	.629
Coal	.418
Oil	1.207
Net total	$3.646
Interest on investment	.56
	$4.206

The total items of expense for this six months' run were as follows:

146.07 tons egg coal	$436.76	
91.00 tons pea coal	183.02	
		$619.78
32,762 galls. oil		$1,791.39
Labor at works		1,394.88
Labor, car filling		670.62
Repairs, etc		565.49
Incidentals		367.03
Net cost		$5,409.19
Interest on total cost of works ($24,285), $118.81 per month		831.67
Total cost		$6,240.86

Total cu. ft. furnished cars	1,483,782
Average cost per 1,000 cu. ft	$4.206
Total number of cars supplied (all classes)	11,806
Average cu. ft. per car	126
Average cost per car	53 cts.

Cost per day (24 *hours*) *Based on Average of* 9,489 *cu. ft. furnished cars for month of January,* 1891.

Labor in gas works	$6.87
Labor of car fillers	4.615
Coal, 2,045 lbs egg Coal, 1,590 lbs. pea	4.12
Crude oil, 224 galls	11.21
Supplies and incidentals	3.885
Repairs	6.185
Net cost	$36.915
Interest on cost of plant	3.8325
Total cost	40.750

Net cost per 1,000 cu. ft	$3.89
Total cost per 1,000 cu. ft	4.295
Lbs. coal per 1,000 cu. ft., 383; cost	0.430⅛
Galls. oil per 1,000 cu. ft., 23 6-10; cost	1.18

It thus appears that the average production is about 45 cu. ft. of gas per gall. of oil, a much smaller result than is obtained abroad. This is partially explained by the fact that the gas in the English reports is measured before compression, while the American figures are for the gas delivered in the car tanks. Mr. AYRES estimates a loss of about 10% by the condensation which takes place on compression, and by leakage.

In addition to this, it is stated that the crude petroleum used in American practice is a thinner and lighter oil than that distilled from shale, which is commonly used in England, or the Russian petroleum used in Germany. The interest on the cost of the works in the above case is excessive from the fact that the building is designed for 8 benches of retorts, whereas only 4 benches are in place, and only 3 of them are working. But even these considerations do not wholly account for the very small yield of gas per gallon of oil, and it is believed that the oil is fed too rapidly to the retorts, so that a considerable percentage is vaporized and passes over without being converted to a fixed gas, and is therefore condensed and carried off with the tar. In English practice the quantity of tar per 1,000 cu. ft. is 4 or 5 gallons, increasing largely when the retorts are underheated, or when the oil is fed too fast. When the tar contains oil it is thin and flows freely, and a drop on a piece of white paper produces a transparent, greasy border around the tar.

A Pintsch gas-works in the same city as the plant for which the above figures are given, but operated by another railway company, showed the following record in three months of the current year:

COST OF COMPRESSED GAS AT GAS HOUSE, INCLUDING THE COST OF RENEWALS, REPAIRS, CAR FILLING, ETC.

Month, 1891.	Quantity.	Total cost.	Cost per 1,000 ft.
February....	352,000 cu. ft.	$643.99	$1.83
March.......	342,000 "	615.33	1.80
April.........	318,600 "	646.04	2.03

Average cost of oil per gallon........	$0.041
Average cost of coal per ton...........	3.55

This does not include interest on the cost of plant. Taking this as 6% on $15,000, we have an additional item of expense of $75 per month. This would make the average total cost of gas per 1,000 ft., including interest on plant, $2.10 for three months.

This, as will be seen, is just half the cost at the works first described, and compares very well with the records of the plants on English railways.

The above two plants are operated by railway companies. The Safety Car Heating & Lighting Co. also operates several gas-works located at different railway centers. One of the largest of these is at

Month.	Yield of gas per gall. oil.	Coal used per 1,000 cu. ft.	Total gas put in cars.	Cost per 1,000 cu. ft. in cars, exclu. of int., but inclu. repairs.	Cost per 1,000 cu ft. in cars, includ'g 10% int. and depret'n.
	Cu ft.	Lbs.	Cu. ft.	$	$
Jan.	65.4	247	797,713	1.98	2.23
Feb.	63	205	684,823	2.59	2.88
Mar.	69.4	212	718,528	2.11	2.38
Apr.	64.1	176	593,959	2.71	3.04
May	61 3	187	607,593	2.39	2.71
June	61.3	185	633,808	2.35	2.66

Mott Haven, supplying gas to cars of the New York Central & Hudson River, New York, New Haven & Hartford, Boston & Albany, New York & New England, and Wagner Palace Car Co. The foregoing table shows the details of cost of gas at these works during the first half of 1891.

The average cost of gas per 1,000 cu. ft. in cars, including interest, repairs, depreciation and charges of every nature, for the above six months, is $2.65. At this rate, gas burned in the 4-flame Pintsch lamps, consuming 2½ cu. ft. per hour, would cost $0.0066 per lamp per hour; or in a car equipped with five lamps the cost would be 3.3 cts. per hour. This, of course, is exclusive of interest on, or repairs and depreciation of, car equipment, or attendance upon the plant on the cars. It should be said that the above figures include not only the cost of filling cars in the Mott Haven yards, but also the cost of transporting gas in tank cars to Grand Central Station and filling cars there, which we are informed increases the cost on the total amount of gas delivered from the Mott Haven works at least 10 per cent.

The Safety Car Heating & Lighting Co. also state that, other things being equal, railway companies can operate works owned by them from 10% to 15% cheaper than a private corporation like the Pintsch Co., owing to cheaper transportation and the advantages due to buying coal oil and other supplies in large quantities and at better prices.

The average yield of gas per gallon of oil is seen to be much higher than at the first works, for which figures were given above; but it is considerably below English records, for reasons already stated.

We are also favored with some data of the Erie gas works at Jersey City, which supply 260 cars and 6 ferry-boats. The works are located in a brick building with 12-in. walls, 28 ft. 4 ins. × 38 ft. 6 ins., on a tract 30 × 115 ft. The cost of the building, with the tank for the gas holder, exclusive of contractor's profit, was $4,100. The plant will make 24,000 cu. ft. of oil gas per day, or enough for 500 cars. The total cost of machinery and fittings in the works was $11,100, f. o. b. New York City. Average daily consumption of gas per car in all kinds of service is taken as 50 cu. ft., the lamps being supposed to burn 4 hours at the rate of 12½ cu. ft. per hour. Coal is burned at the rate of about 100 lbs. per 1,000 cu. ft.

The following figures show the cost of operation of these works for two half-year periods, ending Jan. 1, 1888, and Jan. 1, 1889.

Six Months, Ending Jan. 1. 1888: Coal used, 383 tons, cost, $594.31; oil used, 48,162 galls. cost, $902.63; gas made, 2,697,400 cu. ft.; cost per 1,000 ft. for coal, 22 cts., for oil, 33 cts.—cu. ft. gas per gal. oil, 70.7. Average total cost of gas per 1,000 cu. ft., as follows: July, $1.75; August, $1.77; September, $1.50; October, 1.48; November, $1.33; December.$1.34.

Six Months, Ending Jan. 1, 1889: Coal used, 447 tons, cost, $690.76; oil used, 49,629 galls., cost, $1,903.-94; gas made, 3,430,000 cu. ft., cost per 1,000 ft., for coal, 20.1 cts.; for oil, 55.5 cts; cu. ft. gas per gall. of oil, 69.1. Average total cost of gas per 1,000 cu. ft., as follows: July, $1.37; August, $1.28; September, $1.67; October, $1.44; November, $1.98; December, $1.65.

In the above figures the measurements of gas were made as it passed through the meter before compression. The additional cost of car filling is about 25 cts. per 1,000 ft.; while interest and depreciation, which are not included in the above, may be figured as 10% on $18,000, the total cost of the works. This would make an additional charge of $150 per month, or about 28 cts. per 1,000 for the average monthly output of gas in the 1888 period, and 33 cts. per thousand for the 1887 period. It will be seen from the above that the Erie makes an excellent showing, the yield of gas per gallon of oil being higher than in any other American works reported.

A piece of economy in the operation of Pintsch gas works which has recently been undertaken is the utilization of the waste heat from the retort furnaces for raising steam to run the gas-compressor. It has been the custom heretofore to have a boiler entirely separate from the gas making plant to furnish steam for the compressor, and it requires nearly as much coal to run this as is used to heat the gas retorts. In the Pintsch gas works recently built at Savannah, a steam boiler has been set directly above the retort furnaces. An extra furnace without retorts is provided for use when the waste heat from the retorts does not make sufficient steam. It has not been in use long enough to determine what economy is obtained.

The question of danger in operating the gas works making and compressing Pintsch gas is one which has been much discussed. In the paper by Mr. HUNTER before the Institution of Civil Engineers we find only the following reference to irregular operation of the apparatus:

> While the oil is undergoing the process of distillation, there are several means of ascertaining if this is proceed-

ing continuously, and under the most advantageous conditions. Supposing a given quantity of oil per hour is flowing into the retort, and a suitable temperature is maintained, a glance at the meter will show what quantity of gas is passing and whether it is regular in volume. Should the latter be irregular, it indicates a stoppage, the location of which can be ascertained by reference to the pressure gages, whether in the tar-pits, condensers, washers or purifiers. At the same time the gas would "blow out" from the water safety-valve, alongside the main valve, and also at the siphon oil-pipe; while if anything goes wrong with the gasometer, the gage falls, and a blow out takes place.

Mr. AYRES, in his paper before noted, alludes also to the necessity of keeping watch of the gages and stopping operations in case any of the pipes become choked.

One of the members who took part in the discussion upon Mr. AYRES' paper was Mr. JOSEPH TOMLINSON, Jr., who was a member of the committee appointed by the Society of Arts to adjudicate upon the best system of train lighting. The other members of the committee were MYLES FENTON and Sir FREDERICK ABEL, and as a result of their investigation the gold medal of the society was awarded to JULIUS PINTSCH, of Berlin. Mr. TOMLINSON said that it was not a good plan to place the oil cistern on top of the retort bench. In case of any slight stoppage, the pressure would raise the oil seal and might set fire to the vessel of oil. He therefore placed the oil supply tank on the side of the wall, a considerable distance away, and led the oil to the retorts by a small pipe.

Concerning the above Mr. ROBERT M. DIXON, Engineer of the Safety Car Heating and Lighting Co., furnishes us the following information:

In the proof which you send referring to the question of danger, you quote from Mr. HUNTER. Our practice here does not accord with what he says. We use differential water gages connected with every part of the work, which indicate at once any slight stoppage. Of course we use the safety valve of which he speaks, but never allow the works to become in such a condition as to bring it into use. It is, however, frequently tested by shutting down the main valve of the works, and compelling it to blow off. We make our siphon oil pipes to have such a seal that they cannot possibly blow out. If a gas works is properly run, and it is an easy thing to do, stop-ups never occur. I have spent a great many days in works, and have never been present when there was a stop-up, nor do I know of a case where we have had one that caused a blow-out of any kind. The filling up of the pipes is very gradual, and the differential gages indicate the location of any construction.

We have not placed our oil tanks over the benches for several years past, but have placed them on the side wall of the building.

An accident occurred at the gas works of the Central Railroad of New Jersey in Jersey City last March, and exaggerated accounts were published in the newspapers at the time. The oil supply tank was placed on the wall and a gage glass was attached to it, indicating the height of the oil. This gage-glass was broken and the escaping oil caught fire. General Superintendent OLHAUSEN informed us that the loss amounted to very little, and that the pipes were rearranged after the accident "in a way which will make it almost impossible for another accident of this kind to occur."

The accompanying illustration, Fig. 54 (which may be of practical interest to many users of crude petroleum besides gas makers), shows the arrangement of the oil tank and connecting pipes which was adopted. The crude petroleum is stored in large tanks, usually located some distance from the works. The small tank from which the gas retorts are supplied is placed on brackets, bolted high up on the side of the wall. The tank is a closed cylindrical vessel, and the oil is forced up into it by a small pump, the large storage tanks being on a lower level than the supply tank. To guard against the possible danger of the pump being left running when the tank is full and so bursting it, a pipe runs from the top of the tank through the wall to the outside of the building and connects to an open ventilator, and also to a pipe leading back to the storage tank. It is therefore impossible to put the supply tank under pressure, and if oil is pumped in faster than it is used, all the surplus runs back to the storage tanks.

Attached to the small supply tank, in place of a glass gage, is a piece of 3-in. pipe, connected to the supply tank, and a float is placed within the pipe; an index rod is connected to the float and passes through the cap on top of the tube, indicating the depth of the oil on a graduated scale.

For a final precaution, a bell-crank lever is attached to a cock in the pipe leading from the supply tank to the retort, and two chains lead from it to different parts of the room. If from any cause fire does occur, the oil supply can be shut off without trouble. Besides this emergency cock, there is the micrometer cock, by which the flow of oil into the siphon leading to the retort is regulated; and there is also a cock, just outside the furnace, by which even the small amount of oil in the siphon can be shut off from entering the furnace.

We have been able to find no further evidence concerning the hazard from either fires or explosions in operating Pintsch gas works and no further records of their occurrence. Of course gas manufacture in these works as in other gas works has to be carried on with proper care. Both the gas and the substances from which it is made are inflammable; and if the former is mixed with the proper proportions of air, an explosive compound is formed. Either the lack of proper attention or wilful malice may cause trouble, therefore, as in any gas works although the small amount of gas contained in the apparatus or in the holder would probably limit the effects of even the worst fire or explosion to the immediate vicinity of the works.

To test still further this matter of hazard in the gas manufacture, Mr. W. B. D. PENNIMAN, on behalf of this journal, sent inquiries to a number of railway officers who have had greatest experience with Pintsch gas manufacture in this country. One of the questions asked was: "Do you consider the manufacture of oil gas unusually hazardous to the men engaged in it?" The replies received were uniformly in the negative.

It is to be noted also, in considering the question of hazard, that the force required to operate a gas plant is very small, only from two to four men being on duty at a time. The hazard to life, therefore, even supposing the process to be a dangerous one, is not great.

Our attention has been called to an anonymous circular which was widely distributed sometime ago, containg newspaper extracts describing explosions of oil gas works in three cities. Concerning this the Safety Car Heating & Lighting Co. say:

> The gas works referred to in these circulars were not Pintsch works, or built in any way like them. The construction of Pintsch gas works is such as to make them in every way more safe than any other method of gas manufacture, and their operating history has been such as to obtain the confidence of railroad people. There are now 160 of these plants in daily operation,

We are also informed that the accidents referred to in this circular occurred at works using the Foster gas process, which was introduced on some railways a few years ago by the American Lighting Co., of New York City, a concern which we believe is no longer in existence.

STORING THE GAS AND DISTRIBUTING IT TO THE CARS.

As already stated, the gas passes from the compressor to the storage tanks. These are plain iron cylinders set horizontally. The capacity of those at the Erie works at Jersey City is 265 cu. ft., so with 10 atmospheres pressure, each contains 2,650 cu. ft. of gas, or enough to fill about 20 cars. Of course only a small part of this number could be filled from the holder alone before the pressure would be reduced too low to give a proper amount of gas in the steel tanks on the car. In practice, however, when any considerable number of cars is being filled, the compressor is forcing gas into the holders as fast as it is drawn off. The Erie has five of these tanks at Jersey City to supply 265 cars and 6 ferry boats in service. The West Shore has two storage tanks to supply 150 cars in service. Tanks of this size weigh 6,000 lbs., and cost $760. The fittings cost $125 additional, making the total cost $885.

These storage tanks are really remarkable specimens of metal working. They are 20 ft. long and 4 ft. 2 ins. in diameter, and every seam is welded. In their manufacture the separate rings are first welded, which of course presents no especial difficulty. Each ring is then slightly expanded at one end and enlarged at the other, and the cylindrical portion of the holder is then made by welding together these separate sections. The most delicate operation, however, is welding in the heads, where the only resistance to the welder's hammer is that due to the stiffness of the sheet. These holders are all made at the works of Julius Pintsch in Berlin. The reason for the use of welded instead of riveted seams is, of course, to avoid all leakage.

The amount of storage capacity for compressed gas required at any works depends upon the rapidity with which gas has to be delivered within a given time. If the gas were delivered from the works at a constant rate throughout the day, then two storeholders would be sufficient—one to pump into and one to discharge from alternately. This, however, is never the case, and sometimes large amounts of gas are required within a short time. The storage capacity is therefore arranged for the service, whatever that may be.

The gas as stored after compression does not deteriorate or deposit further hydrocarbon. Samples of gas examined after being stored for 10 months in cylinders at 150 lbs. pressure have shown the same candle power as when first compressed. The reason for this may be seen by remembering that the pressure to which the gas is subjected in the compressor is always a little higher than in the storage tanks, and this in turn is greater than the pressure in the distributing pipes or in the car reservoirs.

The preferable mode of distributing gas from the storage tanks to the cars is to lay a system of underground pipes along the car storage tracks, or where-ever the cars can be most conveniently reached without special switching. In some cases the pipes are carried 10,000 ft. or more from the storage tanks.

The pipe usually used for even these very long lines is ¾ in. extra strong pipe with extra heavy recessed couplings. The joints beween the pipes are made with a paint of litharge and glycerine. When the pipe screws into any special fitting of brass the threads are tinned and the joint is soldered. In case of very long pipes of this small diameter when the flow through them is too slow, one or more store holders are placed at the distributing end to accumulate the gas and facilitate quick filling. At the Pintsch gas works in Chicago, where distributing pipes are in use over two miles in length, a 1¼-in. extra heavy pipe is used for the conducting pipe, and in order to thoroughly protect it and at the same time avoid any loss by leakage, it is laid inside a 2½-in. pipe which opens at the works into the low-pressure gasholder.

At the Central Railroad of New Jersey yards in

Jersey City, ¾-in. piping is laid between alternate tracks to fill cars on either side. Filling valves are placed every 90 ft., and the 50-ft. hose used for filling the car tanks makes it possible to reach any car on the track on either side of the pipe line.

In case it is desired to fill cars at a considerable distance from the gas works, special tank cars are used. For example, at the Grand Central station, in New York City, cars are supplied with gas brought in special tank cars from the works at Mott Haven, 5 miles distant. The tanks which are placed on these cars are of the same size as the storage tanks at the works, 20 ft. × 4 ft. 2 in. They weigh about 6,000 lbs., and the two are placed side by side on the car. When charged to a pressure of 12 atmospheres they will contain over 7,000 cu. ft. of gas at atmospheric pressure. Three tanks could be as well carried on a car if the extra capacity were needed.

At the station where the gas is to be delivered there are generally several storage tanks and a compressor; by means of the latter all the gas in the tank car can be forced into the stationary holders, and the car can then return for another charge. The compressor also makes it possible to utilize nearly all the gas in the stationary holders, drawing from all but one and forcing the gas into this one as the pressure is lowered through the filling of cars from the distributing pipes. In case necessity should require, sufficient gas could be stored at the Grand Central Depot to supply 120 cars for three or four days.

The cost of a system of distributing pipes can be easily estimated by sketching the tracks to be covered, and measuring the length of pipe required. Laying the pipe costs very little, as a shallow trench only deep enough to protect the pipe from injury is all that is required. In passenger train sheds the distributing pipes are often run overhead.

It may be said that leaks in a system of gas pipes under 150 lbs. pressure would be very liable to start fires. But in practice, when they occur they can hardly do harm, since the gas generally escapes first underground and then in the open air or in a large open train shed. The strong odor of the gas also insures that a leak at any point will be detected as soon as it occurs. A small leak, even if it became lighted, would probably do no harm; and if the pipes were underground, the gas would be so disseminated before reaching the surface that it could not be lighted.

A more likely cause of accident, and one which has sometimes occurred, is the starting of a train through carelessness while the tanks are being filled and the hose from the distributing pipes is still connected to the car tank. Of course, in this case the hose is broken, and if the escaping gas reaches a flame it will be instantly ignited. We have been informed of one case of this sort in which the car was being filled in the evening. The man who was filling the tank had a lantern, which set fire to the issuing gas, and he was severely burned.

It is fair to say that the system in use in this case was not the Pintsch, but a compressed gas system using ordinary coal gas. The rules issued by the Pintsch Co. for the instruction of car-fillers call for the use of a safety lantern whenever artificial light is required in filling; but of course this precaution may or may not be enforced by the railway company.

Accidents like that above noted are, of course, always possible, however, and rules, simple enough so that they will be observed, should be established requiring the notification of conductor or engineer that the car-filling hose is to be connected, and later that the work is done and the hose is off. It is to be noted that fire occurring from this cause would always be on the outside of the car, and would occur only at the moment of starting. Danger to passengers from this cause, therefore, may be counted as nil. In proof of this we have the very extended experience with compressed gas of various sorts for car lighting extending over many years. If any injuries to passengers have ever occurred through the starting of cars with the hose connected, they have never been brought to our notice.

The hose used for filling is made of rubber, extra heavy, and is fitted with a cock at each end and a pressure gage at the end next the pipe line. The cocks in the hose are closed before it is disconnected from the car, and thus the escape of the gas contained in the hose while it is being moved from one car to another is prevented, and both the waste of gas and annoyance from its odor are prevented. With this hose it is seldom necessary to use artificial light when filling, as the gage can usually be read by the light from the cars. Even if a light is used, there is no need of carrying it near the cars, as the gage is on the end of the hose next the pipe line.

The length of time required to fill the tanks on a car is from three to five minutes, when two men are at work. When one man works alone a little longer time is required.

Fig. 55 is a diagram showing the length of time taken to fill several cars and the fall of pressure in the storage tank and in the accumulator. The storeholder at the gas works at Hainholz was 18 ft. 4 ins. long and 4 ft. 1⅛ ins. in diameter, making its capacity about 250 cu. ft. From it a pipe of 16 mm. diameter (⅝ in. nearly) led to the car-filling tracks at Hanover, a mile and a half away, where an accumulator of the same size and capacity as the storeholder was placed. The car tanks on each car had a capacity of about 32 cu. ft.

THE PLANT ON THE CAR.

The essential features of the plant placed upon each car lit by the Pintsch gas system are the reservoir for holding the compressed gas, the "regulator" for reducing its pressure to the very low point required for burning and the system of gas piping, burners and lamps. All these parts are shown in the accompanying illustration, Fig. 56, a portion of the car being cut away to show the location of the parts of the plant beneath the car floor.

It will be seen that cocks for attaching the filling hose for replenishing the reservoir are placed on each side of the car, so that on whichever side the line of distributing pipe is located, the car filler can connect the hose without crawling under the car. A pressure gage is attached to the filling pipe near the reservoir (not exactly in the position shown in the drawing). By consulting this gage, the pressure in the gas in the reservoir and the amount available for burning at any time can be ascertained.

The reservoirs used on the car are made of various sizes, from 6 ft. to 9 ft. 6 ins. in length and 16½ ins. to 20½ ins. diam., and of special sizes to order when desired. In ordinary passenger service a single reservoir is all that is required; but where very long runs are to be made, two or more reservoirs may be attached to the car. For example, the Pullman cars running from Chicago to New Orleans (burning nearly a dozen lamps) have four large reservoirs, or enough to last an ordinary car with five four-flame lamps, burned four hours per day, for a continuous service of 17 days. In ordinary passenger service, however, the additional weight and cost of even one extra tank are not often incurred. A single tank, 9 ft. 6 ins. × 20½ ins., holds, when filled to 10 atmospheres, 212.5 cu. ft., or enough to supply an ordinary car, fitted as above, for four days' service, burning the lamps four hours per day.

The reservoirs used in this country are shown by Figs. 56, 57 and 58. They are made of mild steel ¼ in. in thickness. The cylinder is made of a single sheet of metal with a double riveted lap joint. The heads are $\frac{7}{16}$-in. steel, flanged, and fitted in the ends of the cylinder with the ends of the convexity outward. In this way the outward pressure on the heads tends to counteract the outward pressure on the cylindrical shell, whereas if concave heads were used, the two forces would both tend to burst the shell at the ends.

In making the cylindrical shell, after the holes are punched for the rivets and it is bent into shape it is dipped into a bath of tin. The rivets are also tinned and are driven cold; the longitudinal seam is then brazed. The heads are flanged and punched and

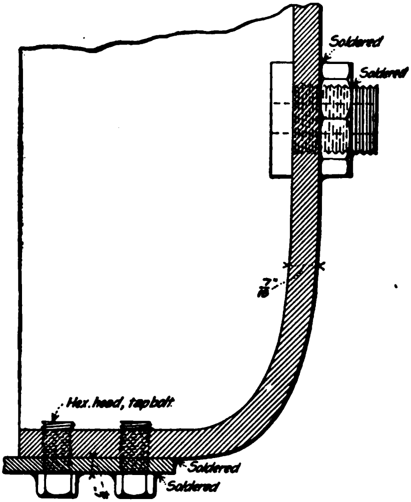


Fig. 58. Detail of Joint Between Shell and Head of Car Reservoir.

the carrier brackets are riveted on (see Fig. 58), and they are then tinned. The heads are fastened in the ends of the cylinders by tap bolts, as shown, and all the joints are carefully soldered. These precautions have been found necessary to make the reservoir absolutely gas-tight under the pressures employed.

Concerning the strength of the cylinder, the tenacity of the mild steel employed may fairly be set at 60,000 lbs. per sq. in. On a cylinder of 20 ins. internal diameter, subjected to a pressure of 150 lbs. per sq. in., the tensile strain per lineal inch on each side will be 1,500 lbs. As the metal is ¼ in. thick, the working strain on the solid metal is only 6,000 lbs. per sq. in. If we take the strength of the double riveted lap joint as 60% of that of the solid plate, we have 9,000 lbs. as its ultimate strength, or a factor of safety of 6. All reservoirs are tested to 250 lbs. pressure or 100 lbs. more than the highest pressure in service.

In English practice the heads of the car reservoirs are made concave, and are welded in; but besides the loss of strength already noted with this construction, there is an additional disadvantage due to the loss in capacity for a given weight and a given space occupied.

One of the most important features of the Pintsch system is the regulator, by which the pressure of the gas in the pipes leading to the lamps is maintained at ½ oz., no matter whether the reservoir be full of gas at 150 lbs. pressure or nearly exhausted. Fig. 59 is a section of the regulator. It consists of an iron, basin-shaped chamber, closed at the top by a flexible diaphragm of prepared leather. The space on the lower side of this diaphragm is filled with gas at ½ oz. pressure, which tends to raise the diaphragm, but motion is opposed by the flat spring connected to the bar supporting the center of the diaphragm. The valve which admits the compressed gas from the reservoir is controlled by this bar, as seen in the drawing, so that when the pressure falls the valve opens and admits more gas from the reservoir.

The important feature of the regulator is the valve, an enlarged section of which is shown in the lower right-hand corner of Fig. 59. To make a valve which shall be absolutely gas-tight against pressure up to 150 lbs. is the problem; for if the valve allows the gas to leak past it ever so little, the pressure will be gradually raised in the pipes leading to the burners. The construction adopted to make the valve absolutely gas-tight is as follows: The opening in the valve seat is only $\frac{3}{32}$ in. diameter. The valve seat is of hard composition metal. The valve is made of a soft alloy and has a parabolic shaped head. When the valve is forced to its seat this soft alloy yields slightly, and a tight joint is formed. In the enlarged section shown on Fig. 59 we have slightly exaggerated the shoulder which is formed on the valve where it comes in contact with the seat after being in use for some time.

To prevent any scale or particle of dust or grit being carried along with the gas and interfering with the closing of the valve, a filter is placed just back of the valve, consisting of brass nettings, between which is placed fibrous material.

The regulator is warranted for five years by the Pintsch Co., and some of them have been in use for 16 years on the railways of Germany without repairs or interference. It is adjusted once for all when made to give the ½ oz. pressure used in the distributing pipes, and needs no further adjustment.

The fact that differences of pressure in the reservoir can have but an infinitesimal effect on the pressure of the gas in the pipes beyond the regulator, may be appreciated by comparing the areas and leverages of the two fluid pressures. The area of the valve-port for the compressed gas is to the area of the regulator diaphragm as 1 to about 9,000. Their relative leverage is as 1 to 25; hence a difference of pressure of 150 lbs. per sq. in. in the compressed gas will be balanced by a difference of pressure per sq. in. on the diaphragm of $\frac{150}{25 \times 9{,}000} = \frac{1}{1500}$ lb. or about $\frac{1}{100}$ oz.

The pipes leading from the reservoir to the regulator and to the filling valves are jointed by tinning the threads and soldering after screwing the pipes together; or where flange joints are used at the junction with filling valves, regulator, etc., a compound rubber and lead gasket is used, the rubber making a tight joint and the lead serving to protect the rubber to a considerable extent from the action of the gas.

From the regulator onward, the gas being under very low pressure, the same care is not necessary in making the joints and an ordinary ½-in. iron gas pipe is used. As seen by Fig. 56, this pipe leads from the regulator to a point underneath the closet, thence upward through the closet to the roof, and thence along the roof of the car, branches being taken off by T connections to supply each lamp. A main controlling cock is placed in the closet and may be turned either to shut off all gas from the car, to give the full opening of the pipe, or to admit the gas through a small by-pass. The last position is the one in which it is placed when the lamps are to be lighted; this avoids smoking the reflector plates of the lamps, which would sometimes occur with the full head of gas when the bowl was open and the wind was blowing. After lighting the lamps the cock is turned to the wide-open position.

Fig. 60 shows a section of the standard lamp of the Safety Car Heating & Lighting Co. The gas is led down to the burner from the roof pipe through one of the hollow supporting standards. From here it passes to the center of the lamp and down to the burners. The reflecting surface above the burners is of white porcelain. A part of the light is reflected upward through the mica chimney and the porcelain shade and lights the head linings. The products of combustion pass up inside the mica chimney and then through four tubes, as shown by the section *A B*, to an exit at the top. The air to supply the flame is taken in at the elliptical openings near the top of the lamp, and in its passage downward, around the tubes just referred to and over the mica chimney, is considerably heated.

The lamps are made with either two, four or six-flame burners. A check screw with lock nut is attached to each burner; and the height of flame is adjusted by this when the lamps are put up, after which it should not be interfered with.

The question of amount and quality of the light from the lamp we shall discuss in a future article, in connection with the photometric tests made by Mr. W. D. B. PENNIMAN.

The lamp globe and shades are packed with asbestos to prevent rattling, and especial care is taken with all joints to prevent them from becoming loose with the constant jar of service. Heavy springs are placed on the gas cocks controlling the lamps as seen in Fig. 61, to prevent them from becoming loose.

In applying the apparatus to a car, pains should be taken to remove all scale and dust from the interior of the pipes by jarring them and blowing through them. Even with this precaution, however, some scale is likely to work loose in the pipe when the car is first put in service. It is recommended, therefore, to disconnect the pipes after the car has been running for a month or so and blow them out thoroughly.

According to data furnished us by the Safety Car Heating & Lighting Co., the Pintsch lighting system is now in use on over 38,000 passenger cars, divided among the different countries, as follows:

Country.	Railways.	Cars equipped.
Germany	30	21,300
France	7	3,300
Denmark	2	45
Sweden	2	230
Switzerland	4	260
Italy	4	1,105
England	15	6,100
Holland	4	767
Russia	11	631
Servia	4	104
Austria	7	1,560
United States	30	2,003
Brazil	2	310
Argentine Republic	4	620
Australia	2	15
Total	128	38,350

In the United States the companies using the Pintsch system and the number of cars equipped by each is as follows:

Companies.	Cars.
Baltimore & Ohio	17
Boston & Albany	35
Central Railroad of Georgia	25
Central Railroad of New Jersey	222
Chesapeake & Ohio	15
Chicago & Erie	48
Chicago & Northwestern	200
Cincinnati, Hamilton & Dayton	11
Delaware, Lackawanna & Western	18
Denver & Rio Grande	88
East Tennessee, Virginia & Georgia	25
Illinois Central	10
New York & New England	12
New York Central & Hudson River	62
New York, Lake Erie & Western	309
New York, New Haven & Hartford	63
New York, Providence & Boston	27
Old Colony	36
Rio Grande Western	40
Rome, Watertown & Ogdensburg	11
Wabash	11
West Shore	111
Pullman Palace Car Co	209
Wagner Palace Car Co	195

The balance, making up a total of 2,003, on the Canadian Pacific, Chicago & Eastern Illinois, Cleveland, Cincinnati, Chicago & St. Louis, Louisville, New Albany & Chicago, Philadelphia & Reading, Richmond & Danville, Third Ave. Cable Road, Cairo Short Line, Long Island R.R. and Chicago, St. Paul, Minneapolis & Omaha.

Pintsch gas-works are in operation, and gas is supplied at the following depots:

Boston	4 depots.	Cincinnati	2 depots.
Stonington, Ct.	1 "	Chicago	5 "
New York City	2 "	Savannah, Ga.	3 "
Jersey City	2 "	St. Louis	Union d'pot
Hoboken, N. J.	2 "	Atlanta, Ga.	" "
We'hawk'n, N.J.	1 "	Denver, Col.	" "
Syracuse, N. Y.	2 "	Ogden, Utah	" "
Marion, O.	1 "	Minneapolis	1 depot.

Concerning the plant attached to the car we find the following in the paper by Mr. Hunter before the Institution of Civil Engineers, from which we have before quoted:

> At the station of the Caledonian Ry., in Glasgow, distributing pipes are laid so that trains can be charged with gas while standing at the station. Pipes are also laid to the carriage shed ½ mile from the works, and carriage can be charged there before being taken out and marshaled. It takes 3 minutes to couple the hose and charge a standard carriage carrying 6 lamps, if they be empty, but this is seldom the case.
>
> Each carriage is provided with one or two recipients or cylinders of a size proportionate to the number of lamps it carries. The recipients are made of $\frac{3}{16}$-in. steel plate, carefully bent. The joints are both riveted and soldered and the flanged ends are then fitted in and fastened by screws and soldered over.
>
> The recipients are charged to six atmospheres (90 lbs. for 36 hours) burning; and no carriage is allowed to leave the Glasgow stations with a lower pressure in the recipients than two atmospheres, or enough for 12 hours' burning.

The paper by Mr. Ayres on this subject, from which we have before quoted, was devoted more to the use of compressed gas for lighting buoys and beacons. We find, however, the following concerning its application to car lighting:

> The application of compressed oil gas to the lighting of railway carriages was first tried in the year 1871 with satisfactory results in Germany, on the Lower Silesian Railway, and in England in 1876, on the St. John's Wood trains of the Metropolitan Ry. The Great Eastern Ry. was the next to adopt it; the Metropolitan Ry. Co. definitely

adopted it for the whole of its rolling stock a few weeks later, other companies quickly following suit. The gasholders are attached either to the roofs or to the underframing of the carriages, and are charged to a pressure of 6 to 8 atmospheres Taking one of the London & Northwestern Ry. Co.'s 6-wheeled, first class carriages as an example, such a carriage carries two gasholders, placed side by side longitudinally, having a collective capacity of 27½ cu. ft. There are seven lamps, burning each 0.4 cu. ft. of gas per hour. A carriage thus fitted will run from Euston to Aberdeen and back, a distance of 1,030 miles, the lamps burning continuously for 33 hours with only one change of gas, the gasholders being charged to a pressure of about 120 lbs. per sq. in., more or less. On arriving back at Euston there is usually about 20 lbs. pressure remaining in the holders. The number of carriages so fitted to date (April, 1888) is 1,462. The cost of the gas delivered into the gasholders, including interest on capital and depreciation of plant. is about 8s. 5d. ($2.02) per 1,000 cu. ft. With the lamps burning 0.4 cu. ft. per hour used on this road, this makes the total cost of the gas burned in each lamp per hour only .0404d. ($.0008).

DISCUSSION.

Mr. Joseph Tomlinson, Jr., presented a detailed table of figures of the cost of lighting the trains on the Metropolitan Ry. The system of lighting in use up to 1876 on that road was ordinary coal gas.

The application of the Pintsch system began in 1871, but was not completed until 1876. As the directors would not invest any capital in making the change, he offered to make it out of revenue if they would give a "suspense account" while the change was taking place. This having been agreed to, he had paid off the whole cost of construction in about three years out of savings, the whole amount being about £9,000. The only charge that went to capital was the gas-works, buildings and fittings, and trucks and holders for distributing the compressed gas. The cost per train mile for train lighting on the Metropolitan Ry., in the years 1873 to 1875, when ordinary coal gas was used, was as follows:

Half year ending June, 1873.	1.50d.
" " " Dec. "	1.44d.
" " " June, 1874	1.59d.
" " " Dec. "	1.65d.
" " " June, 1875	1.52d.
" " " Dec. "	1.54d.

After the introduction of the Pintsch system the cost of lighting per train mile was:

Half year ending June, 1882	0.93d.
" " " Dec. "	0 87d.
" " " June, 1883	0.83d.
" " " Dec. "	0.83d.
" " " June, 1884	0.87d.
" " " Dec. "	0.91d.

NOTE.—The following are further particulars concerning the cost of gas at the first American works, for which figures were given on pages 102, 103.

The total cost of gas in the car tanks per 1,000 cu. ft. was there shown to have reached the high figure of $4.20 per 1.000 cu. ft. in the seven months from July 1, 1890, to Jan. 31, 1891. Besides the fact that the building is designed for a considerably larger plant than is now in operation, which we before alluded to, and the very low yield of gas per gallon of oil, pointing to inefficient operation in the works, we learn that the pipe distributing lines and the filling valves have not been properly looked after, and the result has been a large loss by leakage, which, however, has recently been remedied. That the above high cost of the gas is due to inefficient operation is pretty conclusively proved by comparing the cost per 1,000 ft. on board cars with the cost on three other railways each located within 10 miles of the first-mentioned works.

Name of railway.	Total cost of gas per 1,000 ft. on board cars.
"A" (Seven months ending June 31, '91)	$4.206
"B" (Three months of 1891)	2.10
"C" (Six months ending July 1, '91)	2.65
"D" (Six months ending Jan. 1, '88)	2.11
"D" (Six months ending Jan. 1, '89)	2.095

Oil-Burning Lamps.

Notwithstanding the advances which have been made in lighting by gas and electricity, kerosene, or some form of petroleum product is still the illuminant used in the great majority of the households of the country. So in the railway service, out of over 30,000 cars now running on passenger trains in the United States probably at least 27,000 are lit by oil lamps. In foreign countries rape seed oil, colza oil and some others of vegetable origin are largely employed. The report on car lighting presented at the International Railway Congress, held at Milan in September, 1887, had the following concerning them:

> Rape seed oil is more commonly used than any other material for lighting in Europe. The following are its principal disadvantages: It is irregular; it hardens under extreme cold [European cars not being heated]; it oozes out into the globe and obstructs the light; or drips to the floor and gives forth a nauseous odor. The refilling, cleaning, replacing the globes and wicks and the difficulty of controlling the consumption of oil are also disadvantages Two styles of burners are used, flat and round. Flat burners are more simple in construction, easy to light and clean, require no chimney and are inexpensive. The light is poor, and insufficient air is furnished to the flame; the focus is too high in the lamp. Part of the oil is distilled into the globe. The wick is rapidly carbonized and the lamp burns well only two or three hours. The round burners give a superior light, as the combustion is more

perfect and the flame whiter. For the first 12 hours they remain very constant. It is said, however, that they drip 2 to 3 grams per hour.

From other sources we know well that the defects of the vegetable oils as illuminants are not overdrawn in the above. An American traveler in France a few years ago wrote:

> The car lamps (which burn vegetable or animal oil) are removable and are made to a standard size. There is an opening in the roof to receive them; and before a train starts on its trip a man will be seen walking along the roofs taking out the lamps, passing them down to a man on the platform and replacing them by others that are filled. They are also lighted and manipulated from the roof, and, though they may leak or smoke, the passengers can do nothing with them. It therefore frequently happens that a lamp will leak until the glass beneath the burner is covered with oil, and the flame will be smoking until the light of the car becomes so dim that the passengers can scarcely distinguish each other.

The reason for the use of these oils abroad is partly the high price of kerosene, due to cost of importation, duties, etc., and partly the prejudice against it on account of its supposed danger. These reasons do not exist here. The cost of vegetable oils is far in excess of the cost of the mineral oils used for car lighting; and, as seen above, the vegetable oils are by no means satisfactory illuminants. The question of danger we shall discuss more fully later; but we may say now that the chief danger from oil lamps arises from the spilling of oil in case of an accident; and this danger is practically the same with vegetable oils as with mineral oils.

Concerning the use of mineral oils for car lighting we extract the following from the paper by Mr. GEO. GIBBS, read before the Western Railway Club last spring (ENGINEERING NEWS, March 7, 1891.)

> The grade of oil used until within the past 10 years for car illumination would correspond to the low fire test oil now used for household purposes, gravity about 50°, firing at 150° Fahr, and giving off inflammable vapor at 110°. The unsafe quality of this oil for the purpose was conceded and the invention of improved processes of oil refining and improved burners made possible the use of a heavy, high test oil, so that it is improbable that any of the light oil is in use at the present day. This heavy oil, called "mineral seal," ranges from 36° to 40° in gravity and has a fire test of 300° Fahr.; no inflammable vapor being given off below 230°.
>
> The old oil was undoubtedly highly dangerous, it being possible from improper attention to have it at the temperature of vaporization in the lamp pot; thus a jar, current of air, or defect in the lamp would cause communication of the flame with the accumulated vapor, and explosion would ensue. But the nature of the oil used for car lighting to-day is not popularly understood, many imagining it to be the household quality of kerosene; it is, in fact, totally different, being a heavy oil of difficult inflammability. It may be heated beyond the temperature of boiling water without giving off vapor, and will consequently not ignite in bulk below this point. The flame in the lamp is very sensitive to draft or jar; in fact, it seems impossible for a fire to originate from the light in case of collision, as tearing a lamp from its fastenings would without fail, I believe, extinguish it.

Whether the use of oil of 300° test in place of the common 150° kerosene is universal in railway car lighting at the present time, we cannot pretend to say. Certainly on all railways which make any pretense of keeping up with the times, this change has been made; and indeed the laws of many States require the use of 300° oil on passenger cars; but there may still be a few local roads, which, through ignorance, are still using ordinary kerosene in their car lamps. The difference in price being so low, however, only a cent or two per gallon, the only reason for using oil of low test in railway car lamps at the present time must be ignorance, pure and simple, since with any decently good car lamp the high test oil burns almost as satisfactorily as the 150° oil.

Concerning the desirable qualities in the oil used for car lighting, we cannot give our readers better information than to quote from the admirable series of articles by Dr. C. B. DUDLEY, Chemist, and F. N. PEASE, Assistant Chemist of the Pennsylvania R. R., on "Chemistry Applied to Railroads," published in *The Railroad and Engineering Journal.* By permission of the author, and publisher, we reprint the following from the articles on "Petroleum Products" in the issues of that journal for April and May, 1890, taking so far as possible only those portions of the paper which refer to the purchase and test of the 300° oil, which is alone used for car lighting on the Pennsylvania R. R.

It is probably well known that petroleum, as it comes from the ground, is a mixture of hydrocarbons, which differ from each other, so far as their physical properties go, principally in their boiling points and densities. It is, of course, natural that the attempt to separate these different bodies should be by distillation, and accordingly, so far as we know, the first step in pretty nearly all refining of petroleum, after allowing the oil to settle for a while, is to put it into a still. Heat being applied, of course the constituents of the lower boiling point come off first. In general, we believe the condensed liquid is called "benzine," until the gravity reaches something like 60° or 65° Beaume's scale. Then comes, in general, the 110° fire-test oil, then the 150° fire-test oil, or higher fire-test oil, and still later the 300° fire-test oil. If the distillation is carried far enough, nothing but tar remains in the still. If the distillation is stopped at the proper time, lubricating oil may remain in the still.

All the products of distillation as they come over are more or less contaminated with the heavier parts, and are more or less discolored from the presence of some of the tarry matters, which are either mechanically carried along or pass over in regular distillation. It is customary, we believe, to remove most of the color and tarry matters by treatment with oil of vitriol, which seems to have the power of combining chemically with the tarry matter and precipitating it to the bottom of the tank. Also some of the oils, especially the lubricating oils, are changed in color and improved very much in appearance by filtering through bone black.

The following is the latest revision of the specifications for petroleum products on the Pennsylvania Railroad, dated, as will be observed, September, 1889.

PENNSYLVANIA RAILROAD COMPANY.

Motive Power Department.

Specifications for Petroleum Products.

Five different grades of petroleum products will be used. The materials desired under this specification are the products of the distillation and refining of petroleum unmixed with any other substances and conforming to the detail specifications below. Products having very offensive odor, or being mixed with other oils, will not be accepted. Shipments must be made as soon as possible after the order is received. All shipments received at any place on or after Oct. 1 must show the proper cold test, and all received on or after May 1 must show the proper flash point, and will be rejected if they fail, even though the order did not call for winter and summer oil, respectively, unless it can be shown that the shipments have been more than a week in transit. No preliminary examination of samples will be required, but a limited amount of special preliminary examination will be made on the request of the purchasing agent, for use of parties desiring the information. When a shipment is received, a single sample will be taken at random and subjected to test, and the shipment will be accepted or rejected on this sample. If rejected, it will be returned at the shippers' expense.

The following detail specifications will be enforced:

150° FIRE-TEST OIL.*

This grade of oil will not be accepted if sample:

1. Is not "water white" in color.
2. Flashes below 130° Fahr.
3. Burns below 151° Fahr.
4. Is cloudy, or shipment has cloudy barrels when received, from the presence of glue or suspended matter.
5. Becomes opaque, or shows cloud when the sample has been 10 minutes at a temperature of 0° Fahr.

The flashing and burning points are determined by heating the oil in an open vessel, not less than 12° per minute, and applying the test flame every 7°, beginning at 123° Fahr. The cold test may be conveniently made by having an ounce of the oil in a 4-oz. sample bottle, with a thermometer suspended in the oil, and exposing this to a freezing mixture of ice and salt. It is advisable to stir with the thermometer while the oil is cooling. The oil must remain transparent in the freezing mixture 10 minutes after it has cooled to zero.

300° FIRE TEST OIL.

This grade of oil will not be accepted if sample:

1. Is not "water white" in color.
2. Flashes below 249° Fahr.
3. Burns below 298° Fahr.
4. Is cloudy, or shipment has cloudy barrels when received, from the presence of glue or suspended matter.
5. Becomes opaque, or shows cloud when the sample has been 10 minutes at a temperature of 32° Fahr.

The flashing and burning points are determined the same as for 150° fire-test oil except that the oil is heated 15° per minute, test flame being applied first at 212° Fahr.

---

* We reprint this paragraph simply because of its relation to the testing of the 300° oil, which is alone used in car lamps.

The cold test is made the same as above, except that ice and water are used.

With regard to the burning oils we are hardly prepared to say that we think the method of taking the flashing and burning points which we commonly use, and which with more or less modifications is in common use everywhere, gives a perfectly safe oil, although it should be stated that with most lamp constructions which are in common use on railroads, an experience of now nearly 15 years shows that with oils which pass the tests given in the Pennsylvania Railroad specifications, explosions or accidents due to the oil almost never occur. In the two or three cases which have occurred, some peculiarity in the use of the oil accounted for the accident. In one case a lamp was put behind a stove and the temperature of the oil became very high. In another case of headlgiht oil [150° test] the lamp was so located that heat from the smokebox heated the oil far above any safe limit of temperature.

The explanation of why lamps are in an explosive condition under the circumstances described, is perhaps not at all difficult to comprehend. As has already been described, all the petroleum products are mixtures of hydrocarbons of different boiling points and densities, and the method of separation of these different constituents by distillation makes each resulting product have some of the higher and some of the lower of these constituents. For example, 150° fire-test oil is not exclusively a hydrocarbon which distils at a certain temperature, but a mixture of hydrocarbons of boiling points above and below the temperature corresponding to that at which most of the oil comes over from the still; in other words, ordinary 150° fire-test oil has some light oil in it and some heavier oil in it. This being granted, if the oil stands, as in a lamp half full, the tendency of the lighter parts, especially as the temperature goes up, is to separate from the mass of the oil and become a vapor mixed with the air in the lamp above the oil. If the proportions of air and oil vapor are right, this mixture is an explosive one. However, on the Pennsylvania Railroad no 150° oil even is used where it can have any chance to affect the safety of the passengers, with the bare exception of out-door lamps at small stations for lighting up the platform.

MAKING THE FIRE TESTS.

The apparatus which we make use of is an ordinary small iron cup sand-bath placed above a Bunsen burner, which plays directly against the pan of the sand-bath and heats the sand. In the sand-bath an ordinary porcelain dish, such as are commonly used in chemical laboratories, about 2⅝ in. diameter inside and about 1 in. deep inside, is placed. This is filled to within ¼ in. of the top with the oil to be tested, the amount of oil under test being about one fluid ounce. A thermometer is suspended in about the center of the surface of the oil, so that the bulb is fairly immersed in the oil, but does not touch the bottom of the dish. As a test flame we use a very small gas jet, about as big as the bead of flame on the end of a burning string. We usually draw out a glass tube to a fine aperture and allow the gas to pass through this aperture until we get the size of flame mentioned.

In our experience with open-cup testing, the following variables affect the flashing and burning points: First, rate of heating; second, size and depth of the cup used; third, amount of oil used; fourth, the thermometer; fifth, distance of the test flame from the oil; sixth, the size of the test flame; seventh, the length of time the test flame is held above the surface of the oil; eighth, the place where the test flame is held; ninth, how often the test flame is applied, and tenth, surrounding conditions and peculiarities of the apparatus and manipulator.

In view of this large number of variables, it is, perhaps, not surprising that there should be so much discrepancy in the fire-tests made by different parties, nor indeed surprising that duplicate tests out of the same can should not give exactly the same results. In our experience the most important variable is the rate of heating. It is entirely possible to take a sample of oil and get a higher fire-test by from 5° to 10°, by making the rate of heating very slow, over what would be obtained if the rate of heating were more rapid. So important do we regard this variable of rate of heating that we especially specify it in our specifications. It will be observed that for the 150° oil we raise the temperature of the oil not less than 12° a minute, and for all the other oils we raise the temperature not less than 15° per minute.

The size and depth of the cup affect the fire test in this: if the same amount of oil is in a large shallow cup, the dissipation of the oil vapor into the surrounding air is more rapid than if it is in a smaller sized deep cup, and the dissipation of the oil vapor being a function of the flashing and burning points, in is plain to be seen that these two variables would affect the test. Also whether the cup is filled nearly full or partly full affects the fire test.

The amount of oil affects the test, as is plain to be seen, by virtue of the amount of vapor which is generated. With a large amount of oil, the same rate of heating and other variables uniform, a much larger amount of vapor will be generated in the same time than with a small amount of oil. The effect of the larger amount of oil is therefore to make the test a little more severe on the oil.

The thermometer affects the test somewhat more in its unreliability than in any other way, it being a very common experience with thermometers that they are from 1° to 3° out in their readings, and also that a thermometer which has been used for some time, and especially if the same thermometer has been used to make high fire tests as well as low, gives readings which are unreliable. We usually use what are known as the best chemical thermometers, obtainable from the ordinary chemical supply dealers, and discontinue their use after a few months.

The distance of the test flame from the surface of the oil makes quite a difference in the fire test. If the test flame is put down to within ¼ in. of the oil, the flash and burn will be obtained considerably sooner than if the test flame is held ½ in. or ¾ in. above the surface of the oil. This is, of course, readily understood on the hypothesis previously suggested, that the flash and burn are simply mixtures of air and oil vapor, and it is obvious that the mixture of air and oil vapor, especially in the flashing point, would sooner reach the combustible point at ¼ in. above the oil than ¾ in. above the oil. We usually hold the test flame about ¼ in. above the oil,

The size of the test flame has an influence in its effect on the generation of vapor from the oil. A bead of flame one-half as large in diameter as a lead pencil and maybe ¼ in. long, will give a different result from a test flame as large as a lead pencil and ¾ in. long. This is especially noticeable in burning point, not so much in flashing point.

The length of time that the test flame is held to the oil also has an influence in the effect of the flame on the oil. This is quite clear, we think, without explanation.

The place on the surface of the oil where the test flame is applied is a matter of considerable importance. If the test flame is held near the edge of the dish, a flash will be obtained at a number of degrees lower temperature than if the flame is adroitly passed down near the thermometer to within ¼ in. of the surface of the oil and as adroitly pulled out again. It is obvious why this should be so. At the edge of the dish the oil vapor and the air have the best chance to mix, while in the center of the dish, near the thermometer, the material may be largely oil vapor.

In our view the place where the test flame is held in open-cup testing is the next most important variable after the rate of heating.

How often the test flame is applied affects the test of a very sensitive oil apparently by the influence of the test flame on the surface of the oil. If the test flame is applied every degree, a considerably lower fire test will be obtained than if the test flame is applied, as is our custom, every 7°. It is plain to be seen that the influence of the heat of a test flame on a very sensitive oil would be considerable.

The surrounding conditions have some influence on the test of an oil, notably, the barometric pressure being quite low, the escape of the vapor from the surface of the oil is more easy than with a higher barometric pressure, and in a very sensitive oil this undoubtedly makes some difference. We had a case once in which we were utterly unable to account for the difference obtained in testing the same sample of oil with the same apparatus and same manipulator on several successive days except by the barometric pressure. Furthermore, currents of air passing over the dish are especially important surrounding conditions. It is very clear why this should be so. If the vapor is carried off by a current of air as fast as it is generated, it is obvious that the fire test will be considerably higher than if the vapor which comes out of the oil is allowed to accumulate over its surface. It is not always pleasant to make fire tests of oils in a closed room, but we are very careful in our work to have no currents of air to assist the dissipation of the oil vapor which is set free from the surface of the oil.

It is a question which has been much discussed among users of the petroleum products whether there was any use in taking anything more than the flashing point, since this really measures the dangerous quality of the oil. We are inclined to think the flashing point is abundant to protect the interests of the railroad company, provided the taking of the flashing point is surrounded with sufficient precautions; but as a means of additional security, and especially as a means of neglecting no precaution that could fairly be made use of to prevent accidents with the burning oils, we still adhere to the burning point as an essential feature. Moreover we have found a few oils the flashing and burning points of which were very close together, and from the nature of the distillation we would expect this would be true of oils which represent a very small fraction of the original petroleum so that taking all things into account, it has been deemed advisable to maintain the burning point likewise as a test for all petroleum products used for burning.

COLOR AND CLEARNESS.

In regard to the remaining tests for petroleum products the two burning oils are required to be "water-white" in color, and there are not a few among the refiners who think that a yellow oil gives equally good results in burning as "water-white" oil, and we are hardly prepared to dispute the position. The reason for demanding "water white" oil is that by the ordinary method of distillation the oils contain some tarry matter, unless this is removed, as has been previously described, by treatment with oil of vitriol; and as the demands made on our burning oils are rather severe, we have felt that we were entitled to all precautions possible to prevent clogging of the wicks, the tar, as is well known, remaining in the wicks and causing them to crust. We accordingly demand "water-white" oil. Many times the market falls a little short of "water-white" oil, and what is known as "prime white" is frequently sent in place of "water white." The distinction is not very sharp, and we are ofttimes compelled to accept material than is somewhat less than "water white."

The question of cloudy oil is a very serious one. The most common cause of cloudy oil is due to the following points in manipulation at the refineries where the oil is barreled. The barrels, in order to make them tight, are treated on the inside with a dilute solution of glue. It sometimes happens that owing to carelessness either the gluey solution is not wholly drained out or the barrel is not allowed to become sufficiently dry before the oil is put in. In this case the gluey matter, owing to the shocks of rolling and shaking incident to loading on cars and transportation, becomes thoroughly mixed up with the oil, giving it an opaque or cloudy appearance, which cloudy appearance is very slow to disappear by settling. These little particles of glue or glue and water finely divided, suspended in the oil, are, when the oil is used for burning, soaked up into the wick, and clog it, as will be readily understood. We have had much difficulty from this cause, and the rule is enforced quite strenuously that cloudy oil will not be received. The sample sent for test being, as the specifications state, a sample from a single barrel chosen at random, and the had condition of a barrel when it is full being characteristic of of any barrel in the shipment, it does not always happen that the sample which we receive shows a cloudy appearance, although other barrels in the shipment may do so. To obviate this difficulty, the instructions to the men at the oil-houses are that all barrels containing cloudy oil must be returned to the shippers, they themselves performing the inspection necessary to determine this point. Long standing in a quiet position will cause most of this material to precipitate, but the supply carried at most of the oil-houses demands that the oil be used moderately quickly after it is received, and consequently we have preferred to return cloudy oil rather than attempt to use it.

Mr. W. B. D. PENNIMAN, Chief Chemist of the Baltimore & Ohio R. R., furnishes us the following information concerning the testing of burning oils on that road: The specifications now in force on the Baltimore & Ohio are as follows:

CONDITIONS OF SHIPMENT AND AND GENERAL SPECIFICATIONS.

The material will be purchased by weight. Barrels must be in good condition and must have the name of the contents and the consignee's name and address on each barrel, and plainly marked with the gross and net weight which will be subject to the company's weight.

When received all shipments will be promptly weighed. If not practicable to empty all barrels, 10% will be emptied, and the losses of the whole shipment will be adjusted in accordance with the 10% taken. Should the net weight thus obtained be less by 1% than the amount charged in the bill, a reduction will be made for all over 1%.

Prices should be given in cents or hundredths of a cent per pound.

Shipments, one or more barrels of which are filled with oil cloudy from the presence of glue, or which contain dirt, water or other impurities, will be rejected.

Two kinds of petroleum burning oils will be used, known as 150° fire test for general use, and 300° fire test for use in passenger cars.

DETAIL SPECIFICATIONS.

150° *Fire Test Oil.*—This oil must conform to the following requirements:

1. It must have a flash test above 125° Fahr.
2. It must have a fire test not below 150° Fahr.
3. It must have a cloud test not above 0° Fahr.
4. It must be a "Water White" in color.
5. Its gravity must be between 44° and 48° B. at 60° Fahr.

300° *Fire Test Oil.*—This oil must conform to the following requirements:

1. It must have a flash test above 250° Fahr.
2. It must have a fire test not below 300° Fahr.
3. It must have a cloud test not above 32° Fahr.
4. It must be a "Standard White" in color.
5. Its gravity must be between 38° and 42° B. at 60° Fahr.

METHOD OF MAKING TESTS.

150° *Fire Test Oil.*—The "Open Tagliabue" cup is used for determining the flashing and burning points of this oil; heating the oil at the rate of 2° Fahr. per minute, and applying the test flame every degree from 120° for flash and every 4° after flash for the burning point.

300° *Fire Test Oil.*—The "Cleveland" cup is used for determining the flashing and burning points of this oil: heating at the rate of 5° per minute, and applying the test flame every 5° from 230° Fahr.

CLOUD TEST.

The cloud test is made as follows: Two ounces of the oil are placed in a 4-oz. sample bottle, with a thermometer suspended in the oil. The bottle is exposed to a freezing mixture of ice and salt, and the oil stirred with the thermometer while cooling. The temperature at which the cloud forms is taken as the cloud test.

Mr. PENNIMAN's experience with regard to the color of oil has been that it is useless, if not practically impossible, to get a water white 300° oil. He has frequently made comparative tests of water white oil and oil that was slightly off color, and the results have shown that the quality of the oil was much more dependent upon the gravity and the cold test than upon any other conditions. All of these oils are such complex mixtures of hydro-carbon that oils are often obtained of the same color, same cold test, fire and flash, which give different results in burning. The cold test of 300° oil is, next to gravity, the most important point to be considered; and it is necessary to enforce this requirement strictly throughout the winter.

Lamps.—The improvement in household kerosene lamps which has taken place during the past score of years is a matter with which everyone is familiar. Similar improvements have also been made during that time in the lamps used for car-lighting. The contrast between the smoky, ill smelling kerosene lamp, which was the main reliance for household illumination a score of years ago, and the modern central draft lamps giving a light of 30 or 40 candle power is no greater than the contrast between the old-fashioned car-lamp and the best types of car-lamps now in use.

Lamp Burners.—The ordinary mineral oil lamp of both the oldest and the most modern styles consists of a reservoir of oil, into which dips a fibrous wick. This passes outward from the reservoir through a closely fitting passage called a wick tube. The oil is drawn up through the wick by a capillary attraction and burns at the top of the wick tube. The flame is made bright and smoke is prevented by directing a current of air against its surface. This is done by placing metal deflecting surfaces adjacent to the flame and producing draft by means of a glass chimney.

The above description applies to practically all lamps burning mineral oil; and the manner in which the most perfect modern lamp burner differs from the old fashioned burner with its dim light is first in the means for supplying air to the surface of the flame, second in the means for heating the air before it reaches the flame, and third in the means used to facilitate the flow of oil from the reservoir to the flame.

One of the very first improvements over the plain flat wick burner was the familiar Argand burner, in which the wick tube and wick are annular in cross section instead of rectangular. This had the advantage of giving a strong draft and a hotter and brighter flame. Another improvement which found especial favor for car lamps was the duplex or dual burner, in which two flat wick tubes are placed side by side and the flames from them unite to form a single flame. The reason why this has been especially popular for car lamps is that with 300° oil, which is less fluid than ordinary kerosene, the lamp more frequently grows dim from the sluggish flow of the oil than from lack of air supply. The dual burner gives a double supply of oil to a single flame, while its increased heat also helps the draft and the air supply.

But the greatest improvement over the old styles of mineral oil burners has been made in the invention of the central draft burners. These are similiar to the old-fashioned argand burners, in that the wick tube is of annular cross-section; but they have the additional important feature of a "flame spreader" or device for deflecting the upward air current through the central tube against the surface of the flame.

In most of the central draft burners a current of air is also directed against the outside of the flame, either by a brass deflector or by a corrugation of the chimney. The result of this "forced draft" on both sides of the flame is to greatly increase its temperature and brilliancy. It becomes much whiter than the ordinary kerosene flame, and gives a correspondingly increased light.

Some manufacturers of these improved lamps claim that for a given consumption of oil nearly double the amount of light is given out by the best types of center draft lamps compared with the ordinary duplex burners. Careful experiments, however, do not indicate such a gain. Experiments were made in the Chicago, Milwaukee & St. Paul laboratory, and reported by Mr. Geo. Gibbs, Mechanical Engineer, in a paper before the Western Railway Club last spring (see Engineering News, March 14, 1891) to determine the relative efficiency of several different types of burners. Those tested were the Moehring Argand burner (see "Car Builders' Dictionary," p. E 205, Fig. 872), the ordinary duplex burner, and the Acme, a center draft burner made by Adams & Westlake. The following table shows for each the total candle power in the car, the total cost for oil per hour (at 9 1-5 cts. per gall.), and the cost of the oil burned in cents per candle power hour. We have added to the latter column the figures for the Belgian burner, another improved center draft lamp, taken from the report of experiments make by Major D. P. Heap, U. S. A., for the Light House Board, and from the experiments made for Engineering News by Mr. W. D. B. Penniman, Chief Chemist, B. & O. R. R.

Kind of burner.	Maker of test.	Number of burners in car.	Total candle power in car.	Cost of oil burned per hour. Cts.	Cost of oil per candle power h'r. Cts.
Moehring	Gibbs	13	156	1.67	0.00107
Duplex	Gibbs	13	136½	1.21	0.00088
Acme	Gibbs	7	168	1 94	0.00116
Belgian	Heap	......	......	......	0.00095
Belgian	Penniman	......	......	......	0.00083

From the above table it appears that the central draft burners do not produce much, if any, more light from a given amount of oil than the old Moehring and duplex burners. But though honors are easy in this respect, the central draft burners have a decided advantage in the increased amount of light given out by a single lamp, in their greater freedom from smoking and in the smaller cost of keeping them in order.

On the other hand, it should be said that some of the central draft burners produce so intense a heat as to whiten the glass chimney; and if pains is not taken to guard against it they may also overheat the oil reservoir.

Desirable Qualities in a Car Lamp.—In many respects, of course, the requirements of a lamp for car lighting are the same as those for household lighting; but there are other respects in which the requirements differ.

One important requirement in a household lamp is that it shall not give off a disagreeable odor. The products of combustion of car lamps, however, are generally carried off to the outer air by a ventilating flue over the lamps, so that this requirement is not important here. In almost every other respect however, the requirements of car service are much more exacting than those of household service. The light should not flare, no matter at what rate the car is moving or the wind is blowing, and notwithstanding the drafts that may enter the car through doors, windows or ventilators. The wicks must not jar down with the motion of the car. The lamp tube should be warmed by the blaze enough to facilitate the flow of the heavy oil used in car lamps, yet not enough to heat it anywhere near the point of vaporization. The preferable arrangement of the oil reservoir is on the student lamp principle, so that the oil will be fed by the wick from a constant level. The reservoir should be conveniently removable for filling, but when placed in position it should be securely held in place, and the fastening of lamp, reservoir, or any other removable part should be such as to make it impossible for careless employees to leave lamp or reservoir in an insecure position. Drip from the lamps should be guarded against, for the sake of saving carpets and clothing. Removable glass drip cups effect this admirably. Finally the lamp and its supports should be designed with good taste, yet with such a finish that they may be easily kept clean and bright, for the labor of caring for the lamps is a principal item of expense in oil lighting systems.

Various Styles of Lamps.—That the center-draft lamp not only gives a great volume of light but meets to a good degree the other requirements of car lighting service, seems pretty well proved by the experience of Adams & Westlake, of Chicago, one of the principal firms manufacturing car lamps. They began offering the Acme center draft burner to their customers in 1888; and although the cost of lamps fitted with it is about 20% more than when fitted with duplex burners, we understand that nine-tenths of their orders at present are for lamps fitted with Acme burners. Of this lamp the makers say:

Tested photometrically the Acme burner shows a light many candle power greater than the popular Moehring, Argand or the dual burners which have been heretofore conceded to be the best. The wick is adjusted by a thumb-wheel and ratchet. There is no tying of the wick with thread to keep it in place. There is no cone to the burner, hence no part of the flame is hidden from view and no light is wasted. Its combustion is perfect and the flame is steady, clear and strong.

Another central draft burner in extensive use is made by the Dayton Mfg. Co., Dayton, O. The manufacturers inform us that this burner when tested to its utmost capacity gives a light of 68 c. p. From actual experiments with lamps in use on cars they have found that each burner will average 38 candle power. To remove this lamp from its supports for filling or cleaning, the chimneys are removed and the lamps and reservoir are turned half way around, when they can be readily removed from the lampholder with no danger of breaking the shades.

Another central draft lamp is made by Jas. L. Howard & Co., of Hartford, Conn., and is described as follows:

The oil is held at a uniform level, near enough to the flames to prevent charring of the wick, while overflow is prevented by independent reservoirs to each burner. The construction of the burners allows the regular 1¼ × 6 in. round wicks to be as easily put in as those in the ordinary flat wick burners, and a special friction device prevents their being jarred down by any motion of the car. The oil capacity is so proportioned that they will burn at 50 candle power for 12 hours, or for a longer time if the flame is not carried quite as high.

A "Safety" dome is permanently fixed to the center ring to receive the detachable fount, preventing the possibility of displacing the fount in case of accident. The smoke bells and outside jacks protect the roof from heat by giving free circulation of air between the wood work and the lamp ventilator pipes.

The chimney springs are so made as to prevent their overheating and loss of temper and the oil is fed to the burners on the student lamp principle.

A lamp for car lighting has been recently designed by Mr. WM. WESTLAKE, who was one of the founders of and was for many years connected with the firm of Adams & Westlake, of Chicago; and though the lamp is not yet in practical use on cars, Mr. WESTLAKE's long experience in the design and construction of lamps and his strong belief in this as one of the most meritorious of his designs we believe to be sufficient to warrant its illustration and description here. Coupled with this is the fact that the Belgian burner, which Mr. WESTLAKE has adopted for this lamp, showed in the tests by Mr. W. B. D. PENNIMAN the greatest candle power and the smallest oil consumption for a given amount of light of any oil lamp tested. The list of lamps tested included (with two or three exceptions which we are glad to allow for, lest this statement should seem too sweeping) all the prominent makes of oil lamps for car lighting. The photometric tests of the Belgian lamp we shall describe at length in following pages; but we may say now that it showed an excellent distribution of light as well as high candle power.

As for the degree to which this lamp and burner would fulfil the other requirements of car lighting service, our readers must judge for themselves from the following description. Mr. PENNIMAN's tests were for candle power and oil consumption alone.

The Belgian Burner.—This burner was designed by two Belgian inventors. In its general features it is similar to other central draft lamps. Fig. 61½ shows a vertical section of the burner. Its chief peculiarities are, first, the arrangements for securing a copious flow of oil through the wick, and, second, the peculiar construction of the flame spreader. The wick is woven in cylindrical shape, with an outer and an inner layer, loosely connected, which tends to increase its capillarity. It encircles a fixed central tube, and is moved up or down by an outer tube to which it is attached by projecting barbs. Thus compression of the wick at any point is avoided. To further facilitate the flow of oil, this wick carrying tube is made as an open framework, and has shallow corrugations on its inner surface next the wick.

This wick carrying tube has a rack on one side engaging with a pinion, by which the height of the wick is adjusted. This mode of moving the wick prevents the raising of one side more than another.

The direction of the air currents in the Belgian burner is shown by arrows. It will be seen that the flame spreader is made in two parts, the lower one, a flat disk, the upper, a cone shaped deflector. The disk is pierced by a seriesof small holes. and the air rising through them is heated and deflected by the cone, and strikes the surface of the flame near its top, where smoking and imperfect combustion are most likely to occur.

While this burner has not yet been used in regular service on car lamps, it is among the most popular of central draft burners for household lamps and received the first prize, a gold medal, at the Paris Exposition of 1889. The manufacturers (the Belgian Lamp Co., 31 Barclay St., New York) claim sales of over 600,000 lamps per annum.

The Westlake Lamp.—Fig. 62 shows in elevation and partial section the car lamp designed by Mr. WM. WESTLAKE, referred to above, it will be seen that there is no open space between the top of the chimney and the head lining. The shade is attached to a metal ventilator extending upward to the head lining and connecting with a ventilating jack on the car roof. Thus all heat and products of combustion are carried out of the car, and in addition a considerable amount of ventilation is produced by the current of air induced by the heat of the lamp.

The lamp may be lighted without removing the chimney by thrusting a gaslighter up the central tube. The drip cups are made to swing to one side to facilitate lighting the lamps as well as cleaning the cups.

The construction of the oil reservoir and the lamp supports is evident from the drawing, which shows them lowered from their ordinary position for removing or replacing. It will be seen that the reservoir is surrounded by an air space, and there is a free passage for the heated air with any odor arising from the oil to the ventilating opening at the top of the central suspending tube. These three openings in the car roof are covered by a single ventilating jack on the outside, as shown by the drawing.

Lamps for Exposed Situations.—Where a considerable amount of wind or strong drafts are liable to occur around a lamp, the ordinary duplex burner gives better satisfaction than any form of central draft burner. For lamps in this situation, moreover, special arrangements for air supply are generally made. The lamp supports are hollow with openings near the roof of the car, and the burner is so inclosed that air must pass down these tubular supports to reach it. Thus the points of entrance and of exit for the air used by the lamp are close together, and a reverse draft cannot be set up in the lamp chimney. Of course the friction of the air in passing through these long passages somewhat retards the draft of the lamp chimney; and a longer chimney is needed than with the lamp with open burners.

CORRESPONDENCE.

DAYTON, O., Oct , 7, 1891.

TO THE EDITOR OF ENGINEERING NEWS:

SIR: In your article on oil lamps for lighting, you have indirectly represented that our lamp was an imitation or copy of the lamp made by the Adams & Westlake Co., of Chicago, that is to say, a person reading your article would suppose such to be the case; and as facts are quite the contrary, in justice to the company you should be made more familiar with the origin of the burner.

The writer himself is the inventor of the burner, having gotten it up in 1877 or 1878, and it has been in constant use and has been manufactured since that time by Post & Co., of Cincinnati, and can be seen in their catalogue published after that date. The Adams & Westlake Co. simply changed the manner of raising the wicks to avoid the patent, substituting for the wick raising device of the original burner the old rack and pinion movement; otherwise the burner is practically as originally made. Inclosed please find illustration of original burner taken from Post & Co.'s catalogue for 1881.

J. KIRBY, JR , Gen. Manager Dayton Mfg. Co.

CHICAGO, ILL., Oct. 9, 1891.

TO THE EDITOR OF ENGINEERING NEWS:

SIR: The paper on oil lamps for car illuminating in your issue of Oct. 10 is interesting and in the main satisfactory, but there are a few statements which are not strictly in accordance with the facts.

We are the pioneers in the introduction of the large oil burner for car illuminating, or rather the first ones to offer a large burner that would work satisfactorily. Some years ago a large Argand burner was introduced for railway service by a manufacturer, but the results obtained were so unsatisfactory that the burner was soon abandoned.

We took up the question of large burners a few years ago, spending some six or eight months experimenting before we placed our "Acme" burner upon the market. Since the success of this burner it has been copied by most of the other lamp makers.

In this connection we beg to call your attention to the statement made in your article that "if pains is not taken to guard against it, the central-draft burners may overheat the oil reservoir." The result of actual thermometric test with one of our standard "Acme" lamps shows that after the lamp had been burning continuously for hours in a closed room, free from drafts which would tend to cool the reservoir, the difference in temperature between the atmosphere of the room and the oil in fount was only 10° Fahr., and that the oil reservoir when removed from the fount was not perceptibly warmer to the touch than the surrounding air, and this too without any shade on the lamp to intercept radiation from the burner to the fount. When it is considered that with a car heated to the extreme temperature of 80° the oil in fount would be only 90°, and that the flash test of the oil used is 300°, it will be seen that there is not the remotest danger of overheating the oil. While the whitening of the glass chimney to which you refer may be a weak point in some center draft burners, and was encountered in our original experiments out of which the "Acme" burner was evolved, it is one which we have successfully overcome.

The candle power of the "Acme" lamp given in Mr. GIBBS' paper is away below that shown in many photometrical tests we have made in our shops. We have never laid much stress on the candle power of our lamps *in cents per hour*, as we know from long experience that our railway friends care less about this than about the *intensity of light per burner*. This may seem a somewhat peculiar view of the matter, but when followed up to a conclusion it proves to be grounded on good economy. Supposing, as a basis of comparison, that the "Acme" burner required just as much oil per *candle power* of light produced as the "Moehring," or "Duplex," yet the fact remains that each "Acme" will give out *twice* as much light as one of the others and therefore *three* "Acme" chadeliers will light a car quite as well as *six* of the others. As the items of labor and breakage constitute the chief expense in the maintenance of the lighting system, that burner which necessitates the least number of lamps to a car must clearly be the most economical. Consequently, even upon the showing of Mr. GIBBS, the "Acme" burner requires one half the outlay for lamps in reckoning original equipment, half the labor necessary to care for them and half the number of possible breakages as compared with the "Moehring" and "Duplex."

We should say with the flame of the "Acme" burner at the height used in a railway car, the average candle power would be between 40 and 50; therefore, with a largely increased candle power and but a small increase in the consumption of oil, it is obvious that the "Acme" burner is an advance in the right direction.

In the figures quoted in your table you give the cost of oil per candle power per hour for the "Acme" burner at $.00116. From actual test, a gallon of 300° mineral oil would supply one "Acme" burner for a period of 24 hours, and taking the light at a very conservative figure, say 40 c. p. the cost of candle power per hour, with oil at 9.2 cts. per gall., would be $.00095, or the same as Major HEAP obtained from the "Belgian" burner.

We were the first to introduce the glass drip cup to which you refer, and we agree with you heartily in its advantages over the old style metallic cup.

The use of the cylindrical wick raiser referred to as one of the characteristic features of the "Belgian" burner is not new, and is used on our "Acme" burner. Our wick raiser is an open shell made of perforated metal, thus allowing free access of the oil to the inclosed wick, and at the same time disposing of the rack, for the reason that the teeth of the adjusting pinion engage directly with the perforations of the wick raiser. One advantage of this method is that the wick may be put in the burner at random without turning any particular side toward the burner, as the perforations practically form a continuous rack all around the wick tube. Furthermore, in raising or lowering the wick it is not possible for one side to be raised higher than the other, the wick moving as an entirety.

The flame of the "Acme" burner is remarkably insensible to varying air currents, and in connection with our patented smoke bell and improved roof jack gives a steady, reliable light and admirable ventilation.

THE ADAMS & WESTLAKE CO.

Electric Lighting.

It is safe to say that there has been more work done on the designing and perfecting of electric car lighting systems than on all other systems of car lighting combined. The most progressive railways in America, Great Britain, France, Germany and Belgium have assisted and encouraged the inventors who during the past five years have wrestled with the problem of designing a commercially successful electric lighting system for railway trains. In fact there are few innovations in railway practice which have met with such general favor as the introduction of the electric light for use on trains; and the experiments have been in many cases persistently kept up at a large outlay for a considerable time.

There are many reasons for this popular favor of electric car lighting. Its admitted great advantages in cleanliness, safety, and freedom from heat and odors, the great success of stationary electric lighting, the popular interest in electrical progress, are among the chief reasons. Besides this the electric light is generally considered a luxury; and for the fitting up of the fast express trains which are a prominent feature of modern railroading, luxuries of every sort are in demand.

The great difficulty in lighting trains by electricity is in furnishing the electric current to the lamps at all times and places where it is needed, not only when the train is running, but when it is standing still, when the locomotive is detached, and even when the cars are separated from each other, as in the case of sleeping cars which stand at a station for the entry of passengers for hours, perhaps, before starting on their journey. These difficulties have been met in various ways; and the methods employed for overcoming them constitute the chief point of interest in the various methods of electric car lighting which have been proposed or tried. We may classify these methods as follows:

I. *Primary battery system.*—In which the current is furnished from some form of primary battery.

II. *Storage battery system.*—In which the current is furnished entirely by storage batteries which are charged with electricity from stationary plants at the ends of the trip.

III. *Direct dynamo system.*—In which the electricity is furnished from a dynamo at some point on the train directly to the lamps.

IV. *Combined dynamo and storage battery system.*—In which the storage batteries are charged by a dynamo on the train, and the current from the dynamo is supplemented by that from the storage batteries, or vice versa.

V. *Track wire system.*—In which an electric wire is run along the line of the road and the current is taken from it by a trolley or shoe on the train or on each car of the train.

In order to discuss intelligently the relative merits of these systems it is necessary to understand how much light is likely to be required and how much electrical energy will be required to furnish this light. An ordinary passenger car is well lit with 160 c. p. of light, although more than this is required if brilliant illumination is desired, and considerably more is necessary to satisfactorily light sleeping and parlor cars. European standards of good practice in car lighting are much lower than ours, as was shown in our article on oil lamps. For this reason experiments in electric car lighting have been more readily made there, and have been considered successful; whereas the same experiments, if made here, would have been considered a failure on account of the insufficiency of the light furnished. This fact is to be borne in mind in considering the reports of European experience with some of the systems of electric lighting which have not found favor here.

Taking 160 candle power per car as the amount of light necessary, experience shows that a fairly efficient plant of lamps and wires ought to furnish this from 1 HP. of electrical energy. An 8-car train will therefore require 8 HP.; and remembering that on the express trains, for which electric lighting is chiefly used, several of the cars will be parlor or sleeping cars requiring 40 or 50 more candle power of light, also that the loss in converting chemical or mechanical energy into electrical energy must be provided for, we see that the steam engines of 12 to 15 HP. commonly used for train lighting are none too large for their work.

Taking up now the primary battery system, it is plain that even if no more than 5 electrical HP. are necessary for lighting a train, under existing conditions the primary battery cannot possibly compete with other methods of generating the current. To produce an electric current from a primary battery, zinc or some other metal is burned in an acid bath; and the quantity of zinc and chemicals which it would be necessary to use up in order to produce 5 HP. of electrical energy makes the primary battery out of the question for this as for other places where large amounts of power are required. This question was well handled by Mr. GEO. GIBBS in his paper before the Western Railway Club last spring (see ENG. NEWS, March 7, 1891) in which he stated that the cost of electrical energy from primary batteries was at least 40 times as great as the cost of the same energy from a steam engine and dynamo. Nevertheless, so great is the faith of inventors in their pet hobbies and of the public in the possibilities of electricity, that this system has been repeatedly tried abroad. One train is said to have run for nearly a year between Paris and Brussels lit by electricity from bichromate batteries; and experiments have also been made in England. So far as we can learn, no trial of the system has ever been made in this country. It was reported in 1887 that the scheme was to be tried on the New York Central & Hudson River R. R., and within a few weeks a statement that the New York & New England R. R. was to equip one car with the primary battery developed by the Safety Electric Light Co., of Boston, has been published. A letter from Mr. C. A. COTTON, Electrician of the Safety Electric Light Co., does not confirm this, but says that they "have been very successful, and are preparing for active business."

Of the fifth system named above, furnishing electricity to the train from a wire along the track, it is evident enough that it is not generally applicable to railway service. On a line where trains run very closely and where the same trains are kept running all the time, as, for instance, on elevated railways, there seems reason to believe that this would be an effective and economical method of lighting. Cars on electric railways are generally lit by this system, the current being taken from the trolley wire. On one railway in England and one Russian railway this system is in operation for lighting trains while passing through tunnels. This is, of course, practically applicable only where comparatively few cars are to pass through the tunnel, and to Americans it seems a very roundabout method of reaching a simple end. Instead of wiring and equipping with lamps a hundred or more cars, merely to light them while passing through a tunnel, it would seem manifestly cheaper and better to light the tunnel, arranging automatic devices, if desirable, to turn on the current only during the passage of the train, or perhaps in long tunnels using the lamps only in that section in which the train is running.

There remain, then, three systems of electric train lighting for consideration: the storage battery system, the direct dynamo system and the combined dynamo and storage battery system; and it is by these systems that practically all the electric train lighting has thus far been done.

THE STORAGE BATTERY SYSTEM.

One of the earliest applications of the storage battery after it was perfected to the point of commercial availability was to the lighting of railway trains. In August, 1882, some Faure accumulators, brought to this country from France, were tried for a few days in passenger coach No. 397 of the Pennsylvania R. R.; and so far as we can learn, this was the first instance of railway car lighting by electricity in this country. It was also among the first instances of the electric lighting of a railway car in the world. Experiments were made somewhat earlier in the same year on the Paris, Lyons & Mediterranean Ry. in France, where a train was lit by ten 20 c. p. Swan incandescent lamps (about enough to light fairly well one American sleeping car) furnished with current by a Gramme dynamo, driven by a belt from a pulley on the car axle.

The first instance of the electric lighting of a railway car of which we have been able to find any record was on the London, Brighton & South Coast Ry. in England. In October, 1881, a Pullman car on this road was fitted with storage batteries and employed in regular traffic between London and Brighton. The batteries were charged during the night at London by a special engine and dynamo. The system was soon extended to the lighting of whole trains; but the inconveniences of charging the batteries at the station led to the modification of the system by the addition of a dynamo driven from the car axle.

The results of the Pennsylvania Railroad's first experiments encouraged the belief that when the storage battery was somewhat improved it could be successfully used for electric car lighting. In the summer of 1884, experiments were made at Altoona under Dr. DUDLEY's direction with the Brush storage battery; and their success was such that eight parlor cars were equipped with incandescent lamps and put in service April 1, 1885. Batteries made by the Electrical Accumulator Co. were afterward substituted for the Brush batteries, and seven more parlor cars were fitted with the system in May, 1889. These cars, we believe, are still running.

In 1886 two companies, the Electrical Accumulator Co. and the Julien Electric Co., began actively to push the storage battery for use in car lighting; and as a result of their labors several railways in 1887 began the use of electric lighting from storage batteries on a considerable scale. The Boston & Albany began lighting a Boston suburban train with current from Julien batteries in January, 1887, and on March 29 two express trains between New York and Boston were completely equipped with the electric light. Each car had 22 lamps (16 c. p. each) and a 60-cell battery weighing about a ton. The batteries were charged without removing them from the cars, and as a consequence each train had to lie at either terminus for about 10 hours while the batteries were being charged. Notwithstanding this Mr. G. W. BLOLGETT, electrical engineer of the Boston & Albany R. R., in a paper written soon after these trains began running, waxed enthusiastic over the system and said: "In the near future we may be reasonably certain that electric lamps in the cars will be as common as the air brake and Miller platform."

In the latter part of 1887 the Canada Atlantic Ry.

equipped an express train with Julien batteries, the first run being made Nov. 2, and the Intercolonial Ry. equipped two trains of 9 cars each with the same system. The Burlington, Cedar Rapids & Northern put two trains in service on March 10, 1888. equipped with Electrical Accumulator Co.'s cells. Another, and perhaps the most prominent experimenter was the Pullman Car Co., which equipped two of the New York & Chicago Limited trains over the Pennsylvania Railroad in 1887, one with Electrical Accumulator cells, and the other with Julien cells. Several other companies experimented with one or other of the systems to quite an extent. Thus the sum total of experience with the storage battery was sufficient to enable a fair opinion to be formed as to its merits or demerits for car lighting use.

It must be confessed that this experience has shown considerably more demerit than merit in the system. The excessive first cost, when the train is furnished with enough light for brilliant illumination, and the excessive cost of maintenance, owing chiefly to the short life of the storage batteries, even when handled with the greatest care, are two great obstacles to any general use of the system; but the greatest objection from an operating standpoint is the trouble of exchanging the spent batteries for the charged ones. It is quite out of the question to throw the car out of service for the length of time necessary to charge the batteries. It might be done for a few trains, and has been done by the Boston & Albany and some other roads; but that it could not be generally done with all the passenger trains of a railway is too plain to need proof. On the other hand, to remove a ton of spent batteries from each car at the end of each trip, and replace them by a ton of fresh batteries is a most serious burden, if any considerable number of cars are equipped. Placing the cars in convenient position, holding them there while the work is being done, handling the heavy batteries, and making the connections in proper shape—all these things mean expense and delay. There are, too, other annoyances in the use of storage batteries of which we shall speak farther on. Those already named, however, furnish ample explanation for the fact that the storage battery system of lighting seems to have gone out of use as rapidly as it came in. The Boston & Albany abandoned it in the fall of 1889 after about two and one half year's trial; and we believe that some Intercolonial cars and some Pennsylvania parlor cars are the only ones in America now lit by storage batteries alone. The Khotinsky system, in use on the Fulda-Frankfort and Berlin-Frankfort lines, is the only instance we now recall abroad.

DIRECT DYNAMO SYSTEM.

In this system the use of storage batteries is entirely dispensed with, and electricity is furnished to the whole train from a dynamo placed at some point on the train, and run by a small steam engine. As noted above, almost the first railway train ever lit by electricity that run in 1882 on the Paris, Lyons & Mediterranean Ry. used this system and it has also been tried on a German railway, on the Metropolitan Ry. of London, on the Lancashire & Yorkshire Ry., and on the Great Eastern Ry. A train on the London

& Northwestern Ry. began running Aug. 6, 1884, lit by electricity from a dynamo placed on the tender and driven by a small steam engine under control of the engine driver. This train is still running.

In this country the direct dynamo system was taken up by the Chicago, Milwaukee & St. Paul in 1889. A full account of the system as worked out on that road by Mr. GEO. GIBBS, to whose ingenuity most of its details are due, will be found in our issue of March 12, 1891, p. 235. Briefly, the engine and dynamo are placed in the end of the baggage car or in winter in a separate car designed especially for them, and are started running as soon as the train is made up. Each car is equipped with an auxiliary outfit of oil lamps, which is used to furnish light before the train is made up.

It will be noted that the chief danger of oil lighting (spilling the oil in case of accident) is retained with this system. This could be obviated by the use of candles for the auxiliary lighting apparatus in place of oil lamps, provided the electric system can be made sufficiently reliable to make the use of the auxiliary system while running necessary only in rare instances.

The Chicago, Milwaukee & St. Paul has 62 cars equipped for this system, and finds it much more satisfactory than the combined storage battery and dynamo system, which they tried for a year before adopting the direct system.

There is little doubt that this system is cheaper than any other electric lighting system. For through express trains, where the cars are kept together for long distances, it seems to be well suited.

Whether for trains making runs of moderate length, dropping a car at this junction and picking up another at that, this system could be applied with practical success, may well be doubted. On such trains the auxiliary system would be in frequent use, and the cost of its maintenance, including breakage, cleaning, &c., would be little less than if the car were lit by the oil lamps all the time. Such an expense is hardly one that can be generally borne; and in addition the nuisance of having to light the oil lamps in the whole train every time it was desired to set off a car near the head would be sufficient to condemn it in the minds of most railway managers.

THE COMBINED STORAGE BATTERY AND DYNAMO SYSTEM.

This system is in more extensive use for train electric lighting than all other electric systems combined. It is susceptible of much variation, according as the dynamo or the storage battery is made the prominent feature. At one extreme the storage battery is considered merely as an auxiliary to relieve the dynamo of excessive load and furnish light in case of stoppage. At the other the storage battery is the main feature and the dynamo is introduced to keep the battery charged and avoid the delay and the handling of the batteries at terminals, which we have seen to be chief objections to the storage battery system used alone. Another point of variation is in the disposition of the storage batteries, which are sometimes distributed to each car and arranged to keep the lights burning when the car is cut off from the train, and in other systems are all placed underneath the baggage car floor. Of course, this latter plan cuts off the light from the cars in case the train is broken. the same as the direct dynamo system ; but the disadvantages which at present attend the use of storage batteries, such as fumes, decay of car timbers through leakage of acid, and necessity of frequent repairs are, of course, less important when the batteries are all in one place. The wiring is also simpler, cheaper, and perhaps less liable to derangement with the storage batteries close to the dynamo than when they are distributed through the train.

Another point in which systems differ is in the method of driving the dynamo. A favorite method abroad has been by a belt from a pulley on the car axle. This was tried on the Connecticut River R. R. by Mr. S. H. BARRETT ; but it has never been used in this country to any extent. We believe, however, that the system of electric train lighting on which the engineers of the Consolidated Car Heating Co. are now at work, will take power from the car axle to drive the dynamo, and will use storage batteries on each car.

ELECTRIC TRAIN LIGHTING IN ENGLAND.

The advantages of driving the dynamo from the car axle instead of by a separate engine are not a few. The heat, steam and vibration of the engine are avoided, the latter especially being sometimes quite serious. The space occupied by the engine is probably less than that by the belting connections from the car axle; and the system is claimed to be cheaper, both in first cost and cost of operation, than the system using a separate engine. The mechanical difficulties in devising an apparatus which will automatically connect and disconnect the dynamo as the train rises above or falls below the necessary limits of speed seem to have been successfully met abroad; and in England this system is the one in most extensive use for train electric lighting.

The London, Brighton & South Coast Ry., of England has had a long experience with this system, having used it since 1883. In the early part of the present year 16 trains were running on that road lit by electricity, and 6 more were being fitted. On the whole, electric lighting seems to have been effected there with as little inconvenience and at as moderate cost as on any railway in the world. The average train lit is 10 cars in length, and has 40 to 70 lamps of from 8 to 16 c. p. The dynamos have a maximum capacity of 5,000 watts (nearly 7 electrical HP). The accumulators are all on the car which carries the dynamo, so that the train cannot be broken without extinguishing the lights.

The system as used on that road was the joint invention of Mr. HOUGHTON, electrician to the company, and the late WM. STROUDLEY, its mechanical superintendent. In a paper before the Institution of Civil Engineers in 1885, Mr. STROUDLEY described the general features of the system, and presented a drawing illustrating the apparatus for driving the dynamo from the car axle, which we reproduce herewith (Fig. 63). A great merit of this system from the economical point of view is the small attendance required. An inspection and oiling is made at the end of each trip, but no regular attendant is required on the train. The cost of skilled attendance is the largest item in the maintenance account of the American systems which use a special engine to drive the dynamo.

Notwithstanding the apparent success of this system of electric lighting, the managers of the London, Brighton & South Coast have recently determined to discard it and adopt the Pintsch gaslight system in its place. Whether it was the matter of expense, the inconvenience of not being able to split up trains without extinguishing the lamps, or some other reason that led to this decision, we are not informed.

The apparent success of this system on the London, Brighton & South Coast, however, has led to its adoption by several other British railway companies. The Great Northern began lighting a train with electricity on this system in July, 1886, and has 8 trains now running fitted with it. Two trains have been lit by this system on the Taff Vale lines and two others on the Cheshire lines. In all these cases the storage batteries are all located in the "guard's van," and the dynamo is also located there and is driven by belting from the car axle. The system is therefore open to the same objections which we found inherent in the direct dynamo system. The train cannot be separated without extinguishing the lights.

To obviate this difficulty the Midland Ry. has modified the system by placing storage batteries on each car of the train, and has six trains now running equipped in this manner. This system was recently described at length by Mr. WM. LANGDON in a paper before the Institution of Civil Engineers. The main points of interest in the installation are as follows:

Both the "parallel" and the "series" system of wiring have been tried; but the latter has been adopted as being manifestly the best, although it requires somewhat larger wire in the circuits. The first trains fitted had dynamos which gave a constant current output when a certain speed had been attained; but for later work a dynamo made by Holmes & Co., of Newcastle, which gives a current proportional to the resistance of the circuit and of constant electromotive force, has been employed. Carbon brushes are used on the dynamos, having been substituted with much advantage in place of the wire gauze ones formerly employed. They are placed radially to the commutators, the lead being automatically altered to suit the direction of rotation.

On the spindle carrying the armatures there is also arranged a reversing switch, actuated by friction disks which come into contact when the spindle slows down, but run free on its attaining any degree of speed. The duty of this reversing switch is to insure that the current shall always be in one direction, whichever way the vehicle is running.

Fig. 64, which we reproduce from the plates accompanying Mr. LANGDON's paper, illustrates the method of driving the dynamo from the car axle. It will be noticed that the driving gear is double, to prevent stoppage of the plant by mishaps to either belt. The pulleys on the axle are 21 ins. diameter, those on the countershaft are 16 ins. diameter, and the dynamo pulleys are 9 ins. diameter. It is not claimed that the arrangements shown are the most efficient that could be devised, as the proportions adopted were largely determined by the location of parts of the car gear which it was not desired to interfere with. The total weight of the dynamo with bed plate is 1,680 lbs., and the weight of the countershaft, pulleys, &c., is 1,456 lbs.

The storage batteries used are of the "E. P. S." type, supplied by the Electrical Construction Co. Where trains are not to be uncoupled, the practice is to put the dynamo in the guard's compartment and the battery cells in an adjoining one. On main line trains each vehicle carries its own storage batteries, 18 cells being awarded to each, giving a current of 35 volts. Mr. LANGDON advises in arranging accumulators in the train to set them so that the plates will be longitudinal with the train, to prevent them from breaking away from the shoulder piece to which they are attached. To avoid the possibility of an explosion from the accumulation of hydrogen, there should be provision for good ventilation of the cells and of the place in which they are stored.

Where the accumulators are all in the guard's van, the total weight of batteries used is 3,572 lbs. for one set of batteries or double this weight for two sets. Where accumulators are placed on each coach, the weight per vehicle is 1,000 lbs. for vans and coaches with seven compartments and 720 lbs. for coaches with six compartments. As to durability, the positive plates have lasted nearly two years, and some of them are now being replaced.

The electrical couplings on the Midland have been designed with much care to secure a coupling which can be easily and certainly made and which will provide good electrical connection. Indeed, Mr. LANGDON considers this one of the most important details of an electric train lighting system; and he believes that steps should be taken toward the adoption of a uniform design and location for such couplings.

Besides the six trains equipped with the system outlined above, the Midland Ry. has 4 trains fitted with different types of motor connected direct to the dynamo. These with the respective weights are as follows:

	Weight of:		
Motor and dynamo.	Combined apparatus.	Case.	Total.
	lbs.	lbs.	lbs.
Parson's electro-turbo generator	1,064	448	1,512
Newall engine and Kapp dynamo	1,512	224	1,736
Brotherhood engine and Holmes dynamo	1,987	336	2,323
Rigg engine and Holmes dynamo	2,016	1,008	3,024

These dynamos and motors are set in their cases on the rear of the tender and take steam from the locomotive boiler, the steam supply being under the control of the engine driver. The entire apparatus is not touched from the beginning of the trip to the end, according to Mr. LANGDON. It is intended to make a careful comparison between the system of driving from the axle and driving by independent motor and determine which method gives the best results.

To care for the electrical apparatus on these ten electric lighted trains, a staff of six train attendants and a manager is provided. Two men are at the London terminus and four are at principal stations, where their duty is to inspect the apparatus on arriving trains, and if necessary ride through the next section and see that all is right.

In answer to the question whether the electric light is safe and reliable, Mr. LANGDON says that the electromotive force of the current employed (35 to 50 volts) is so low that a child could suffer no harm from it. There is no reason why the same safety which characterizes its use in stationary practice should not attend its use in lighting trains. The experience in train electric lighting, too, has now been extensive enough to make the fact that no casualties have thus far occurred from it one of some importance.

As to reliability, it is undeniable that failures have occurred; but Mr. LANGDON contends that they have in all cases been due to causes which can be traced and obviated. It is true that the lights are not as brilliant when operated by the battery alone as when the dynamo is at work, unless the capacity of the battery is unusually large; also that slight variations in the light may occur when the train travels at very high or very low speed (in the system taking power from the car axle). But unless the parts are improperly proportioned, there is no such variation as to interfere with the comfort of the passengers.

The total number of railway carriages now lit by electricity in England, according to Mr. LANGDON, is 365 coaches and 57 vans.

In the discussion on this paper it was pointed out that the use of electric light necessitated an additional coupling between the cars. Mr. W. F. PETTIGREW described experiments with a train of ten cars lit by 35 lamps, current being furnished from a rotary high speed engine and dynamo, mounted on the locomotive boiler. With this system, however, the equipment of seven locomotives was necessary in order to handle only four suburban trains, and this seems to be a marked disadvantage in placing the dynamo on the locomotive. Mr. W. H. PREECE alluded to experiments made by him in 1884 on the London & Southwestern Ry. A train was fitted with an air compressor driven from the car axle, and the compresed air was used to drive a small 3-cylinder engine which turned the dynamo and maintained the light when the train was standing still. The plan failed from its expense, and because every carriage had to contain the source of the light. At that time he had little faith in storage batteries; but now no electrical device is coming into use more rapidly, and he believed that in fourteen years there would be 160,000 railway carriages fitted with electric lights.

Mr. STEPHEN TERRY described a system of train lighting built by Messrs. Bumstead & Chandler and Crompton for use on the Government Railways of Cape Colony. The system is the "direct dynamo" without storage batteries (described above). An independent boiler is used, furnishing steam to a tandem compound engine. The whole plant is placed in the guard's van, and exclusive of the boiler weighs only 1,210 lbs. Two trains lit by this system have been in use for about two years, and two more have just been put in service.

AMERICAN PRACTICE IN THE COMBINED DYNAMO AND STORAGE BATTERY SYSTEM.

The chief user of the electric light on railway trains in America has been the Pullman company. Their early introduction of the storage battery system to light two of the Pennsylvania limited trains between New York and Chicago, we described last week. Very soon, however, the charging or changing of the storage batteries at the terminals was found to cause too much delay and expense; and while the storage batteries were retained under each car, thus rendering it independent in case of necessity, an Eickemeyer dynamo and Brotherhood 3-cylinder engine, taking steam from the locomotive boiler, were placed in the baggage car to keep the batteries charged and light the train. A space in one corner of the baggage cars, 3½ × 6 ft. 3 ins., is partitioned off with lattice work; and the engine and dynamo are placed inside, both being mounted on one cast-iron bed-plate. The steam from the boiler is passed through a reducing valve, and reaches the engine at a pressure of about 60 lbs. The exhaust steam is passed into the car heating pipes, which causes about 15 lbs. back pressure. Both engine and dynamo are automatically lubricated, the supply of oil being sufficient for two round trips. The dynamo at 900 revolutions gives about 80 ampères of current of 80 volts E. M. F.

Under each car are 32 storage battery cells, weighing with their boxes about 1,300 lbs. When the dynamo is running, the batteries furnish about 30%

of the current, and when the dynamo is not running, they of course furnish all the current. The batteries are charged by running the dynamo several hours during the day when the lamps are not lighted. An attendant (whose salary is $90 per month) makes the trip regularly with the train, and an expert also examines the train at the terminal stations. The perfection of the details of the system in use on the Pullman trains has been chiefly due to Mr. A. H. BAUER, the manager of the Pullman Company's electrical department. The system is in use on the Pennsylvania Limited trains between New York and Chicago, the Chesapeake & Ohio's "F. F. V." express trains between New York and Cincinnati, and on a number of the important express trains between Chicago and principal Western points.

COMPARATIVE COST OF DIFFERENT ELECTRIC SYSTEMS.

On the question of reasonable cost more than on any other, the practical success of electric car-lighting depends. Everyone admits that the electric light is cleaner and more pleasing than any other, and lends itself more readily to decorative effects. It can be divided into smaller units than any other, and can be placed in more advantageous positions; for instance, it may be used for reading lights or berth lights. It is absolutely unaffected by drafts. It maintains its original candle power better on the whole than any other light, and is less dependent for its excellence on the faithful care of the trainmen. Its safety will hardly be questioned; and while it is confessedly a little weak in the matter of reliability, yet if installed and maintained with proper care it ought to be reliable enough to dispense with anything but candles for auxiliary lighting.

Conceding, then, these important advantages of the electric light, the question as to the advisability of its use turns upon matters of cost and convenience. Or, to adapt an old proverb which is peculiarly pat in this case, we must see whether the candle is worth the game!

Further, as the merits of the electric light itself are pretty much the same, no matter what system is used for providing the current, the question what system of electric lighting is best suited to compete with gas, oil and other systems in use, is also one of comparative cost and convenience.

We have already seen that the track wire system, while possibly applicable with advantage to elevated railways, is manifestly unsuited for general use; and that the primary battery system* is certainly out of the race on account of its great cost if for no other reason. The storage battery system, too, has had a thorough trial; and, as at present operated, its expense and inconvenience have proved it to be inapplicable to general service. The field is narrowed. therefore, to the direct dynamo system and the combined dynamo and storage battery system.

The fact that the former system requires the train to be kept solid and makes all the cars dependent on the plant in the baggage car for light is a practically insurmountable objection to the general use of the system. On express trains making long runs, and neither taking on or setting cars off on the trip, this system may be used, perhaps, without great inconvenience. Yet even here the cars have to be equipped with a complete set of oil lamps at all times ready for use. The stoppage of engine or dynamo from any cause, the breakage of the steam supply hose, the separation of the train for any of the many causes which make such separation necessary in railway service, an accident to the baggage car necessitating its withdrawal from the train,—any of these various causes may leave the train in darkness until the oil lamps can be lit.

---

*At the International Railway Congress held at Milan, Italy, in September. 1886, it was stated that a car was running between Brussels and Paris lit by 14 electric lamps of 10 c. p. (nominal) furnished with current from primary batteries. The first cost of equipment is $972. The cost of operation is about 73 cts. per hour for the car, or a little over 5 cts. per lamp hour, or ½ ct. per candle power hour. The battery cells have to be charged with new liquid every fourth trip, and new zincs are supplied every sixteenth trip.

Of these objections, those of most importance—the necessity of keeping the train solid and the extinguishing of the lamps whenever the train is separated—apply with equal force to that form of the combined dynamo and storage battery system in which the storage battery cells are all located on the same car as the dynamo.

The conclusion is irresistible, then, that the only system of electric lighting thus far tried which stands a chance of competing in general service with other well known systems of car lighting is the combined dynamo and storage battery system, in which each car is supplied with sufficient storage battery cells to light it for a considerable time, independently of the current from the dynamo.

But while this system is admittedly the superior in convenience, the direct dynamo system and the system having storage battery cells on one car only are certainly cheaper systems in first cost, and might perhaps be preferred by a railway manager equipping a few express trains only, with electric lights. We have therefore collected figures of cost for each of these systems as follows:

Direct Dynamo System.—The fullest and most reliable figures available for this system were given by Mr. GEO. GIBBS, Mechanical Engineer of the Chicago, Milwaukee & St. Paul Ry., in his paper before the Western Railway Club last spring (ENGINEERING NEWS, March 14, 1891). He gave the following as a close estimate of the cost of equipping and operating a 50 ft. standard passenger coach with this system, the coach to have nine lamps, of 16 c. p., in the main body and one in the closet:

First cost of equipment	$395.40
Cost of equipment per candle power	2.47
Depreciation and 5% int. on first cost	36 35
Total running cost per car per hour	9.83 cts.
" " " " lamp "	.98 ct.
" " " " candle power per hour	.061 ct.

The "first cost of equipment" includes $113 for auxiliary oil lighting equipment for each car, consisting of 6 Acme lamps in the main body and one in the closet. It also includes each car's proportion of the cost of the "light and heat tender," or separate car on which the engine, dynamo and boiler are placed, figuring on the basis of one tender-car to each 15½ cars in service. The depreciation is figured at 10 % on the tender car and its equipment and 5 % on the wiring and the oil lamps. Lamp renewals are computed as part of the total running expenses.

The details of these "running expenses" for one trip in the month of October, 1890, were given as follows:

Train of	**10 cars.**
Running time	**11 hours.**
Maximum lamp load	**152**
Average lamp load	**87.3**
Indicated horse power hours	**85.6**
Water per indicated horse power hour	**57.8 lbs.**
Water per trip for lighting	**4,948 lbs.**
Evaporation at boiler pressure per pound of coal.	**5.7 lbs.**
Coal used per trip	**868 lbs.**
Lamps per indicated horse power	**10.5**
Coal per indicated horse power hour	**10 lbs.**
Cost of coal per ton	**$2.00**
Cost of coal per horse power hour	**1 cent.**
Attendance	**$5 25**
Lamp renewals (3 at 40 cts)	**1.20**
Oil and waste	**.40**
Miscellaneous supplies and repairs	**.80**
Coal for light	**.87**
Coal to haul car	**2.00**
Total cost per trip	**$10.52**
Or, per car per hour	**9.54 cts.**

This is the running cost alone; but the interest and depreciation on the original equipment amounts to little in comparison. That little, however, should properly be added. Taking Mr. Gibbs' figures of $36.35 per car as a fair estimate of this, we have 11 hours' service per trip for the car and, say, 300 trips per year, making 3,300 car hours, or 1.1 cts. per car hour in addition to the running expenses. This makes the total cost of this system 10.93 cts. per car hour, 1.09 cts. per lamp hour (16 c. p.) and 0.068 cts. per candle power hour.

The Metropolitan Ry. of England (better known as the London Underground) experimented with this system in 1884. The train had 52 lamps of 18

c. p. each, and the light was used 8 hours per day The cost of lighting, not including labor, was estimated at 1.375 cts. per lamp per hour. The cost of labor would probably double this, making the cost about 2.75 cts. per lamp hour. It is to be remembered, however, that an enormous advance in electrical matters has been made since the date of this experiment. The improvements in lamps alone, which are now very much cheaper and far more durable, would materially alter these figures.

The London & Northwestern equipped a train with the direct dynamo system in August, 1884, which has been running ever since. The following figures concerning its cost were given by Mr. J. W. FLETCHER, the company's electrician, in the discussion on Mr. LANGDON'S paper (abstracted on a previous page).

The first cost amounted to £2 4s. 1d. ($10.24) per lamp (16 c. p.) and "their experience of the first year's running" gave the cost per lamp hour at 0.628d. (1.268 cts.)

Estimating interest and depreciation at 10%, and annual service at 3,300 hours we have the total cost as 1.271 cts. per lamp hour or 0.08 ct. per candle power hour.

Combined Dynamo and Storage Battery System with Battery Cells All on One Car.—As stated above, the London, Brighton & South Coast Railway has had the most experience with this system. The following figures for the cost of its installation and operation were published a year ago as coming from Mr. HOUGHTON, the company's electrician:

The trains on which this system is used consist mostly of 10 cars which run solid (that is are not broken up), and average about 40 lamps (12 c. p.) to a train. The total weight of the plant on each train is three tons; the cost of plant is £400 ($1,940), and the cost of maintenance per annum is £65 ($315). The only attention given the trains is at each terminus, where one man inspects the apparatus and oils the pulley bearings.

If we estimate interest and depreciation on the above original investment at 10%, this brings the the total cost per annum to $509 per train. If the number of lamps is 40, of 12 c. p. each, and the hours service per annum is 3,300 (the same as estimated for the Chicago, Milwaukee and St. Paul above), we have the total cost as 0.385 cts. per lamp hour, or 0.032 cts. per candle power hour.

The Connecticut River road has had considerable experience with the system in which the battery cells are all located on the baggage car; but it uses an engine to drive the dynamo instead of taking power from the car axle, experiments with the latter method having resulted unsatisfactorily. It has been stated that the first cost of equipping the train on this road, 71 lamps being used, was about $2,500. Also that the annual cost of operation was as follows:

Interest on capital (6%)	$150
Lamp renewals	50
Sinking fund	100
Repairs and attendance	30
Coal and stores	156
Total	$486

Estimating as before 3,300 hours service per annum, this makes the cost (for 71 lamps on the train) about ⅕ ct. per lamp hour. This, however, is manifestly much lower than the actual cost, since there is nothing allowed for an auxiliary system of lighting; and the "sinking fund," which is supposed to cover depreciation, is evidently inadequate.

Combined Dynamo and Storage Battery System with Battery Cells on Every Car.—In Mr. GIBBS' paper above referred to he gave an estimate of the cost of installing and equipping this system, based on the experience with it on the Chicago, Milwaukee & St. Paul. The system, which was practically the same as that in use by the Pullman company (described above), was used for a year on two trains on that road. The weight of storage batteries on each car was 1,500 to 2,000 lbs. Mr. GIBBS' estimate, based on this experience, for the equipment of a standard 50 ft. passenger coach, having 9 lamps in the body and one in the closet (all of 16 c. p.), was as follows:

First cost of equipment	$863.00
Cost of equipment per candle power	5.40
Depreciation and 5% int. on first cost	137 47
Total running cost per car per hour	13.20 cts.
" " lamp "	1.32 cts.
" " c. p. "	0.082 ct.

The "first cost of equipment" includes the storage batteries, the car's proportion of engine and dynamo and $113 for auxiliary oil lighting equipment. Depreciation is figured at 25% on the Brotherhood engine, 10% on the Eickemeyer dynamo, 33⅓% on the storage batteries and 5% on wiring and oil lamps.

Adding the charge for interest and depreciation to the running cost, estimating 3,300 car hours service per annum, as before, we have a total cost with this system of 17.36 cts. per car per hour, 1 74 cts. per lamp hour, and 0.102 ct. per candle power hour.

The cost of this system as used on the Pennsylvania limited trains by the Pullman Palace Car Co. was given as follows by Mr. CHAS. SELDEN, Superintendent of Telegraph, B. & O. R. R., in a paper read at the Telegraph Superintendents' Association Convention in 1889:

	First cost of equipment.	Annual depreciation.*	Int. at 5%.
Baggage car....	$1,840.25	$156.03	$93.19
Day coach..............	461,87	121.66	26 26
Sleeper.......	504.23	185.22	31.07
Dining car.............	486.58	158.74	29.07

On the above basis Mr. SELDEN estimated that a train consisting of baggage, smoker, day coach and two sleepers would cost $3,772.45 to equip. Depreciation would amount to $769.79, and interest to $207.85, making a total of $977.64 for "fixed charges." An attendant at $90 per month would cost $1,080 per year, making the total cost per year for the train of 5 cars $2,057.64. The total number of lamps on the supposed train is 85; and estimating the hours of service per annum at 3,300, as before, we have the total cost as 0.734 ct. per lamp hour or 0.046 ct. per candle power hour. It will be noted that Mr. SELDEN's estimates for depreciation are much below those of Mr. GIBBS; and he makes no allowance for auxiliary oil lighting equipment nor for the cost of coal, oil and waste.

The figures thus far given are all estimates. We have, however, been favored, through the courtesy of Mr. **William Garstang**, Superintendent of Motive Power of the Chesapeake & Ohio, with the following figures of the actual cost of the electric light on the limited express trains between New York and Cincinnati running over that road:

---

* Mr. SELDEN estimates depreciation on engine at 10%, on dynamo at 3%, on storage battery cells at 16.4%, on lamps at 700%, shades at 10%, lamp sockets at 10% and nothing on wiring or other apparatus.

For the 12 months ending June 30, 1891, the total cost of labor and material used in operating electric light on Chesapeake & Ohio trains was	$13,110.04
Making the cost per day	36.40
The average number of electric lighted cars in operation per day is 10, and the average number of lamps per car is 12, making the cost per lamp per day	.30
Assuming that the lights are in actual service 12 hours per day, the average cost per lamp per hour is	2½cts
And per candle power hour is	.156ct

This, it is to be noted, is for running expenses alone; interest and depreciation (so far as the latter is not made good by current repairs) are not included.

Mr. A. H. **Bauer**, Superintendent of Electrical Equipment of the Pullman Palace Car Co., has furnished us the following figures showing the cost of operating the electric lights on the Pennsylvania Limited trains:

First Cost of Equipment for 6-Car Train:

Baggage car	$2,250
Dining car	576
Three sleeping cars at $675	2,025
Observation car	625
Total	$5,476
Average cost of labor per car day	$1.15
“ “ “ material per car day	.74
“ “ “ operation per car day	$1.89
Average number of lamps per car	28
Average cost per lamp per day	6¾ cts.

Mr. BAUER states that their practice is to base all calculations on 24 hours per day, which is correct for estimating the cost of train lighting as used on the Pennsylvania Limited, because the manner of running the trains necessitates using nearly as much light during the day as at night. On this basis the cost per lamp per hour would be but little over ¼ ct., or including interest and depreciation, estimated at 10%, and supposing the car in service 300 days per annum, the cost per lamp hour is only 0.29 ct. This is not fairly comparable with the other figures given, however, being on such a different basis as to hours of service per day and number of lamps per car. In the table below, therefore, we have used the same hours of service per annum (3,300) for this as for the other estimates given.

On the Midland Ry. (England), as described last week, the dynamo is driven from the car axle, but storage battery cells are placed beneath each car. The first cost is given by Mr. LANGDON at £50 ($243) for a "6-bodied coach" having 12 lamps (8 c. p. each). The cost of the dynamo and running gear is £250 ($1,215). At one dynamo for each 10 cars fitted, this would add $121.50 as each car's proportion of the first cost of the generating plant, making the first cost per 16-c. p. lamp $60.75. No more definite idea of the cost of operation of the system is given by Mr. LANGDON than that his experience "inspires him with the belief that the cost per 8-c.p. lamp per hour will eventually be considerably less than ¼d. (½ ct.)." It is perhaps fair to conclude from this that the cost at the present time is somewhat in excess of this, or at the rate of over 1 ct. per 16-c. p. lamp per hour.

To admit of ready comparison of these different figures of the cost of electric lighting, we have tabulated them as follows:

SYSTEM AND ROAD.	Total cost per lamp hour.	Total cost per candle power hour.	*Remarks.*
Direct dynamo:			
Chic., Mil. & St. P....	1.09 cts.	.068 ct.	Careful estimate.
Metropolitan (1884)....	2.75 “	.153 “	Short experiment.
London & No. W'n....	1.27 “	.080 “	Probably accurate.
Combined system: Battery on one car.			
Lond., B. & So. Coast.	0.385 ct.	.032 “	No charge for power used.
Conn. River...........	0.200 “	.013 “	Incomplete.
Combined system: Battery on each car.			
Chic., Mil. & St. P.....	1.74 cts.	.102 “	Careful estimate.
Pullman Company,—			
Selden's estimate....	0.734 ct.	.046 “	Incomplete.
Bauer's statement.....	0.713 “	.044 “	
Chesapeake & Ohio....	2.500 cts.	.156 “	Excluding int. and depreciation.

It must be admitted from the above showing that the use of the electric light is hardly advisable at present for any railway which is not willing to go down deep into its pocket to pay for the luxury. We believe Mr. GIBBS' figures to be the most accurate of any of the estimates in the above table; and he explicitly stated in giving these figures that the low cost was only attained through unusually favorable circumstances. If this is the case, the conclusion is inevitable that electric lighting in the present state of the art is not applicable for general use in lighting railway cars. The direct dynamo system we have seen to be certainly unavailable, on account of its inconvenience; and if 1¾ cts. per lamp hour is a minimum for the total cost of the combined system with storage batteries on each car, it certainly cannot compete for general use with the established methods of car lighting.

On the other hand, it must be freely acknowledged that the last has not been heard from electric car lighting, and that it is by no means unlikely that it may yet become one of the most common systems of train lighting. A study of the detailed items of cost in Mr. GIBBS' estimate for the direct dynamo system shows that nearly half the total operating expense is for attendance, and 20% of the remainder is for the coal used to haul the special car used. If, now, the electrical generating apparatus can be so simplified that it can be placed in charge of the engine-driver or baggage master, and be located in the baggage car or on the tender, about 70% of Mr. GIBBS' expense account will be wiped out. This has been done in England; it ought to be possible here.

The next most important step will be to improve the storage battery, and so increase its durability, efficiency and capacity that its use under any passenger car will be practicable. This is a task on which many inventors are at work; and able electricians look for their success.

With these two steps taken, and with such other improvements in the whole apparatus as may confidently be expected, the cost of train lighting by electricity may be reduced to a point where it will compare favorably with that of the long established methods of car lighting.

Further than this it would be useless to prophecy, for the possibilities of improvement in the efficiency of electric lighting apparatus are so great that a single discovery may possibly upset even our conclusion above that the primary battery has no chance in the race. Necessarily we have dealt in this paper only with the present state of the art, when the best incandescent lamp gives to us in the form of light only about 5% of the energy existing in the electric current which it uses, or perhaps 4% of the energy imparted to the engine which drove the dynamo. But Geissler's tubes, which are still a laboratory toy, are said to convert as much as 30% of the electric energy imparted to them into light. When Nikola Tesla or Elihu Thomson or some other electrical expert finds a way to double, quadruple, or multiply tenfold the efficiency of the electric current as an illuminant, the problem will be wholly changed, and electric lighting may then become the standard method of car illumination.

The Comparative Photometric Value of Oil, Gas, Gasoline and Electric Lights.

Photometric tests of the different systems of car lighting were made for ENGINEERING NEWS by Mr. W. B. D. PENNIMAN, Chief Chemist of the Baltimore & Ohio R. R., in the laboratory of the Johns Hopkins University. The photometer used by Mr PENNIMAN (the Dibdin radial photometer) is described and illustrated on page 12. As stated in the note on page 21, the following description of the photometric tests, with their results, was intended for publication immediately afterward.

But in making these tests, besides determining accurately the light given out from the various lamps, careful measurements were made of the amount of illuminant burned; and in making these measurements it was discovered for the first time that the Frost gasoline system, instead of burning carbureted air, or air saturated with gasoline vapor, as claimed by its makers, was burning most of the time nearly pure gasoline vapor. The evidence was strong from this that the gasoline in the carbureters was being boiled by the heat from the lamp; and an investigation of this matter was made, with the results reported at length on page 74 *et seq.*, and showing as clearly as experimental evidence could well show anything, it appears to us, that such boiling of gasoline was a common if not in-variable feature of the plant as then being manufactured and introduced by the company.

The reader will now understand the reason why the publication of the exceedingly valuable and important series of tests below was delayed until after a description of each of the various systems had been published. It was impossible to judge fairly the photometric results obtained from the gasoline system until it was known whether the gasoline was burned under the same conditions as in ordinary practice.

It was represented to us that Mr. FROST, the inventor of the carbureter system, who himself set up the carbureter and lamps used by Mr. PENNIMAN in testing this system, was so anxious to get a high candle power that he made the apparatus burn much richer gasoline vapor than is usual in regular practice. The carbureter manufacturers themselves, however, made no claim of this sort. In fact, they could hardly do so, as their own representative had set up the carbureter and directed its working. Since then, too, other tests, described on page 79 *et seq.*, have proved pretty conclusively that the carbureter system in these tests was worked with no richer vapor than it often uses in regular service (if we except the considerably different system used on the Pennsylvania Railroad, as to which no records are available). We may therefore conclude that the results in candle power given below for the carbureter or gasoline system fairly represent what may be obtained from the plant in the form tested in ordinary practice, the vapor burned being nearly pure gasoline steam with little admixture of air.

We regret that we have been unable to obtain anv photometic record of the inverted Lungren burner when burning gas from the carbureter plant as introduced and now used on the Pennsylvania Railroad. The results from this form of the plant with the burners first used (and still largely used) are shown in Figs. 71 and 72. The far less candle power shown in these diagrams as compared with Fig. 70 would seem to indicate that there is much truth in the claim that the Pennsylvania form of the plant does not produce a gas in which gasoline steam in excess of the capacity of saturated air is burned; but what, if any, difference would result in the candle power shown in Fig. 70, if the burners were supplied with this different gas, we are unable to say. It proved impossible to arrange for the further tests which we desired to have made.

The same facilities were extended to each of the companies controlling each system of lighting in setting up their apparatus and regulating its working. As stated above, the inventor of the Frost carbureter system set up that plant to his satisfaction. The Pintsch gas plant was set up by **Mr. R. M. Dixon**, Chief Engineer of the Safety Car Heating & Lighting Co., which controls the system in this country. The oil lamp fitted with the Belgian burner was furnished complete, ready for testing, by the Belgian Lamp Co., of 31 Barclay St., New York City, and the standard mineral sperm oil in use on the Baltimore & Ohio R. R. was used in the fount.

PHOTOMETRIC STANDARDS USED.

Photometry is the measurement of the relative amounts of light emitted from different sources. The methods employed always consist of the determination of the relative distances at which two sources of light produce equal intensities of illumination. The relative intensities of the lights are then to each other inversely as the squares of their distances.

The unit of measurement is the light emitted by one sperm candle (made 0.85 in. in diameter and six to the pound), burning at the rate of 120 grains per hour. The "standard candles" are specially made for this purpose, and are all imported. In practice two are almost always used, and a correction is made for the variation of candle burned. The results are rejected if this variation exceeds 6 grains on either side of the prescribed quantity.

The use of candles, however, in a test extending over some time is hardly feasible, especially when powerful lights are to be tested, on account of the great difficulty of securing proper conditions. These can only be secured even for a short time by considerable patient attention and skill.

As the intensity of the lights varies inversely as the squares of their distances, it is evident that when the distances from the screen are approximately equal, any inaccuracy in placing the standard makes a much less serious error than if a lower standard is used.

In the tests herewith recorded, as the standard was to be moved constantly and the lights to be tested were of an intensity many times greater than the light from two candles, it was decided that a light of greater power was desirable.

For example, suppose it were attempted to test a 50 c. p. light by a 1 c. p. standard, and let the distance between the two lights be D. Then the screen would stand at a distance of $\frac{1^2}{50^2} D$ from the 1 c. p. light or .0004 D, and a change of say 1 c. p. to 49 c. p. would only require the screen to be moved to $\frac{1^2}{49^2} D$ from the 1 c. p. light or $\frac{1}{2401} = .000417\ D$, a difference of only 0.000,017 D, or .0017 in. if $D = 100$ ins. On the other hand, if the same 50 c. p. light is being tested by a 20 c. p. standard, the distance of the screen from the standard light will be $\frac{20^2}{50^2} D = 0.16\ D$. A loss of 1 c. p. will then require the screen to be moved to $\frac{20_2}{49^2} D = \frac{400}{2401} D = .16674\ D$, a difference of .00664 D or 0.664 ins. if $D = 100$ ins., a movement about 400 times as great. It is thus plain that the nearer the adopted standard corresponds in candle power to the light to be tested, the greater will be the possible accuracy of the test.

The standard used in these tests was the light issuing from a slot on the chimney of an Argand burner. This slot was adjustable in size; and it was set to 10 c. p. by means of an ordinary Bunsen photometer. One of the candles was then extinguished, and the screen was moved to the point where the light was equal on each side of the screen. If this reading did not indicate a candle power of exactly 10 candles, the operation was performed again. Two slots were standardized in this way and finally one was tested against the other.

The slots were tested again at the expiration of the evening's work, and the results were rejected if any change in intensity was noted. The "standard light" used in the tests was varied according to circumstances.

The greatest variation admitted in results does not exceed 4%. All proper precautions were taken, by the use of suitable screens, against errors due to the glare of reflected light in the operator's eyes.

As already noted, the ordinary method of determining candle power has been heretofore by horizontal measurements only, that being a sufficiently accurate mode of measurement for ordinary lamp, gas or candle flames, in which the horizontal rays are the strongest. For many of the modern forms of burners, however, as also for all forms of electric lights, and for all lights of any kind in which the light is thrown downward from reflectors or from an inverted burner, this is a most inadequate unit of comparison, and the modern practice for accurate light measurements is far better, viz., to determine the candle power on a series of equidistant angles below the horizon, from which a "mean circular candle power" is determined. In this way, and by the methods above described, all the following diagrams of candle power (Figs. 65 to 72) were determined as tabulated in Table IX.

But it will be apparent that, from the nature of a candle-power unit, it is only a comparative one, and gives no measure of the absolute illumination from a lamp at any given distance. The same light has the same candle power at all distances, though the absolute intensity of its light decreases as the square of the distance. What we really wish to know about car lamps for car lighting, however, is the relative amount of light which they make available in what we may call the **VISUAL PLANE** of a car, viz., the plane in which a book or other object on which light is needed is held by an average passenger. This plane, as will be seen from the upper part of Fig. 74, is about 4.5 ft. below the car lights when placed at their usual height. To represent the intensity or value of the light supplied *along this plane* at any point, we must plainly introduce some other

TABLE IX.—CANDLE POWER OF VARIOUS CAR LIGHTS FOR EACH 10 DEGREES OF ARC BELOW THE HORIZONTAL.

Kind of light and burner used.	Belgian oil, 2 lamp chand'r.		Pintsch Oil-Gas Burners.				Frost Carburet-ers.			Factor for computing visual units.
	Without shade.	With shade.	Present, 6-flame.	Present, 4-flame.	Old 6-flame.	Porter regen've	Present, Lungren.	Old Excelsior.	Old Dudley "P. R. R."	
Fuel per hour.	3.5oz.	3.5oz.	4.72 cu. ft	2.75 cu.ft.	3.65 cu.ft.	3.0 cu.ft.	3.97 oz.	2¼ ±	2¼ ±	
Hzl	60.0	72.0	64.6	47.4	51.2	29.1	80.8	50.1	38.7	0.00
10°	52.8	72.0	65.4	46.7	51.2	38.4	85.0	45.2	38.7	0.03
20°	52.8	72.0	65.6	45.9	50.3	43.4	83.3	43.0	40.6	0.12
30°	42.4	51 6	64.2	36.1	45.3	49.3	81.6	36.1	30.1	0.25
40°	42.4	51.6	62.6	36.1	46.0	54.8	85.7	30.5	24.6	0.42
50°	30.4	41.0	59.0	32.0	41.2	54.9	79.4	27.0	19.5	0.59
60°	19.6	33.6	70.2	42.8	41.2	51.6	77.1	10.8	17.0	0.75
70°	10.8	22.4	62.6	45.9	41.2	73.5	71.1	7.4	11.1	0.88
80°	4.0	19.8	61.6	37.8	45.7	53.5	71.1	5.1	6.6	0.97
90°	2.4	18.4	52.5	34.9	40.3	55.5	74.4	4.8	4.5	1.00
Circular mean.	31.82	45.47	63.37	40.50	44.22	49.08	79.10	25.84	23.31	....

unit than that of the candle power, which shall take into account the absolute intensity of the light at each point along this visual plane, as well as its relation to a candle-light.

For this end we have used what we may call the VISUAL UNIT of *one candle power at a distance of* 4.5 *ft.*, that being the usual vertical distance in passenger cars between the source of light and the "visual plane" where light is needed by passengers. The manner of determining this "visual unit," as also the number and distribution of the visual units from each of the sources of light tested, is indicated in Fig. 73.

The visual units ($V\text{-}U$) are thus determined:

Designating the source of light as L, and the candle power of any ray as $C\text{-}P$, for any ray vertically downward from L to the visual plane we have, by definition:

$$V\text{-}U = C\text{-}P.$$

For any other ray of candle-power $C\text{-}P^1$, standing at an angle of D° *with the vertical* (the candle-power diagrams, Figs. 1 to 8, have the angles recorded from the horizontal), we have for the visual units in the ray at the point where it strikesthe visual plane:

$$V\text{-}U^1 = Cos^2\,D \times C\text{-}P^1$$

since the intensity of the ray varies inversely as the square of the distance, and the length of any oblique ray from L to the visual plane is to the length of a vertical ray, as $\frac{1}{Cos\,D}$ is to 1. Therefore, having given the candle-power values of the rays from any source of light, L, at successive angles of 10° from the vertical, we may determine the value in visual units of each ray, at the point where it cuts the visual plane, by multipling the value of each ray in candle-powers by the coefficients *Cos*^{2} *D*, which are as follows:

D.	Cos D.	*Cos*^{2} *D.*	Angle from horiz.
0°	1.	1.	90°
10°	.9848	.9698	80°
20°	.9397	.8830	70°
30°	.8660	.7500	60°
40°	.7660	.5868	50°
50°	.6472	.4189	40°
60°	.5000	.2500	30°
70°	.3420	.1170	20°
80°	.1736	.0301	10°
90°	.0000	.0000	0°

These coefficients (between the rules above) are given at the end of Table IX., showing the observed candle-power of the several rays of each light tested. The recorded candle-power, multiplied by these coefficients, gave the table of visual units in Table X. From this Table X. of visual units the diagram shown in Fig. 73 was constructed, which shows the distribution and number of the visual units from a single lamp *striking on a plane perpendicular to the ray* along the horizontal visual plane.

From this diagram (Fig. 73. alone much information of value can be had, which is not to be had from candle-power diagrams alone, and some of which we shall shortly note; but to derive all the advantage which may be had, three other facts must be considered, and two (at least) other diagrams constructed from it, as given in Figs. 74 and 75. These facts are:

1. The light derived from lights which the passenger faces is worthless to him, or worse than

worthless; it makes it harder rather than easier to read or see about the car. In less degree this applies to the rays coming vertically downward, because:

2. A book or other object in the visual plane on which light is needed cannot be held so as to be perpendicular to all the rays which reach it from a series of lamps, and it is naturally held at an angle of about 45° to the vertical.

TABLE X.—VALUE IN "VISUAL UNITS" (ONE C. P. SHOWN AT A DISTANCE OF 4.5 FT.) OF THE LIGHTS SHOWN IN TABLE IX. IN A HORIZONTAL PLANE 4.5 FT. BELOW LIGHT. LIGHT ASSUMED TO STRIKE A PLANE NORMAL TO THE RAYS.

Kind of light and burner used.	Belgian oil, 2 lamp chand'r.		Pintsch Oil-Gas Burners.				Frost Carburet-ers.			Factor for computing visual units.
	Without shade.	With shade.	Present, 6-flame.	Present, 4-flame.	Old 6-flame.	Porter regen've.	Present, Lungren.	Old Excelsior.	Old Dudley "P. R. R."	
Fuel per hour.	3.5 oz.	3.5 oz.	4.72 cu. ft.	2.75 cu.ft.	3.65 cu.ft.	3.0 cu.ft.	3.97 oz.	2¼ ±	2¼ ±	
Hzl deg	......	......	......	......	......	...	......	......	......	
10°	1.6	2.2	2.0	1.4	1.5	1.2	2.5	1.4	1.2	
20°	6.2	8.4	7.7	5.4	5.9	5.1	9.8	5.0	4.8	
30°	10.6	13.0	16.1	9.0	11.3	12.3	20.4	9.0	7.5	
40°	17.6	21.4	25.8	14.9	19.0	22.6	35.5	12.6	10.2	
50°	17.8	24.0	34.7	18.8	24.2	32.2	46.5	15.8	11.4	
60°	14.6	25.2	52.6	32.1	30.9	38.6	59.9	8.1	12.8	
70°	9.6	19.8	55.2	41.5	36.3	47.2	62.8	6.5	9.8	
80°	3.8	19.2	59.8	36.6	34.6	51.9	69.0	4.9	6.4	
90°	2.4	18.4	52.5	34.9	40.3	55.5	74.4	4.8	4.5	

From Table X. the diagram (Fig. 73) showing value in visual units of the several illuminants is constructed.

The *full* value in visual units, therefore, is realizable and realized only from rays at an angle of 45°, perpendicular to a plane at an angle of 45° with the horizontal. The value of all other rays which strike this surface is diminished as the *cosine* of the angular deviation of the ray from 45° is to 1. The little table of cosines above, however, will show that until this deviation exceeds about 25°, in other words, for rays at all angles between 20° and 70° (inclusive) with the horizontal the loss from this obliquity of angle is not material, so that all rays lying within those angles may be taken to have their full illuminating value in visual units, although only one of these rays can strike the surface of a book precisely perpendicular thereto. On the other hand, rays striking the book within 20° of the horizontal or vertical must have their unit value in visual units diminished. But to do this is a comparatively simple matter, because:

3. The seats in a car are usually spaced about 3 ft. apart, and the lights either 6 ft. or 9 ft. apart, or 2 to 3 seats. In a sleeping car the seats are placed back to back, that is all. There are many variations in the spacing of both lights and seats, but the variations outside of the above limits are too small and few to be of moment.

This being so, the interior view of a car shown at the top of Fig. 74—which is modified from a drawing of a standard Pennsylvania R. R. passenger car fitted with the Frost carbureter (gasoline) light—will at once make clear: 1. That all the rays striking the visual plane of any seat from any lights in the car, strike it within the limits of 20° and 70°, and consequently may be taken at their full value in visual units, *excepting* the rays from a light which is directly over a seat, or nearly so. These rays strike the surface to be illuminated in the visual plane at an angle of about 45°, and consequently their value in visual units must be multiplied by Cos 45° (.7071, aken as 0.7 as a sufficiently exact approximation) to get their true illuminating value.

This being determined, we may deduce from Fig. 73, which gives the value in visual units at any point along the visual plane of the rays from a single light of the various kinds tested, the total *useful* value of the light reaching any seat from all the lights in a car, spaced in any way devised. This is done in Table XI., the results of which are plotted in Figs. 74, 75.

For example, take lights spaced 6 ft. or 2 seats apart, and the seat directly under a light. It is illuminated by (1) the light directly overhead, (2) by a light 6 ft. back, (3) by one 12 ft. back, and so on indefinitely.

We first read from Fig. 73 the value in visual units of the vertical rays: These are to be multiplied by 0.7 to get their visual value.

Then, on the vertical line marked 6 ft., Fig. 73, we can read off the value of the light reaching the same seat from a light 6 ft. back; from the vertical line marked 12 we get the value to the same seat of the lamp 12 ft. back; from the vertical line marked 18, we get the value to the seat of the next line, 18 ft. back, and so on. The value in visual units diminishes so rapidly that lights more than 15 to 18 ft. back have little effect on the total, as will be seen in Table XI., which was thus compiled. It gives for each kind of light tested and for each car-seat between lights spaced either 6 ft. or 9 ft. apart, the light from *each* lamp or burner in the car which contributes a sensible amount of useful light to it, which are the lights between a point vertically over it and 27 ft. back of it; the visual units of vertical rays, as read off from Fig. 73, are first multiplied by the coefficient 0.7 as recorded above, and all the other readings from Fig. 73, for lamps 3 ft. or more behind the seat, are recorded as read off.

The total of these illuminations from all the lamps within 27 ft. of a seat gives, within a trifling margin of error, which does not affect comparisons, the *total useful illumination striking each seat in a car from all the lights therein, in effective visual units;* or in other words it gives the number of candle powers at a distance of 4.5 ft. necessary to give the same light for reading, etc., with the rays striking perpendicular to the pages of a book or other surface as ordinarily held.

Of course these diagrams (Figs. 74, 75) apply with precision to such seats only as are fortunate enough to have a series of 3 to 5 lights behind them. Seats toward the back end of the car receive less light; but the amount of light derived from lamps more than 6 to 9 ft. back of a seat is so small that practically the diagrams may be regarded as applying to all the seats.

Such diagrams have never before been constructed or attempted, and we need hardly say that they illustrate certain truths as to car-lighting of no small importance, which it is well to bring out in definite form. As one point of especial importance they show that neither the horizontal nor vertical rays are of much real use. The perfect light as regards distribution should minimize these rays, and put as much of the light as possible into the rays lying between the angles of 20° and 70°.

The most conspicuously successful of the lights in this respect are the two old Pennsylvania standard burners for the Frost carbureter system known and marked as the "Dudley P. R. R. standard" and the "Excelsior." Both of these lamps not only put the light where it does most good, but produce a substantially perfect and uniform distribution of the light in the visual plane, whether the lamps be placed 6 ft. or 9 ft. apart. As a consequence, although the total volume of light throughout will be seen to be comparatively trifling, yet they were felt to give a very satisfactory illumination, by no means so inferior to the new inverted burners as the candle-power diagrams indicate at first sight.

Next to these in evenness and excellence of distribution, and far ahead of them in total visual units of light, come the 2-flame and 4-flame Belgian lamp chandeliers. The Belgian lamp was described on page 154, and the results obtained from it are taken as representing the best present practice in car lighting with oil lamps.

It should be mentioned that in testing all the oil lamps only a single lamp was burned, as the nature of the photometric apparatus requires, and the power of a 2-lamp or 4-lamp chandelier was obtained by multiplying the candle-power of one lamp by the number of lamps. This is not quite exact theoretically; but is sufficiently accurate for practical purposes.

A more important consideration is that the candle-power of any oil lamp is greatly affected by the skill and care used in managing it—adjusting the wick, etc.—so that an oil lamp under test is likely to show considerably more candle power than will the average of a hundred burned as in service. In far less degree, all the systems of gas lighting show less candle power in daily service than under the skilled manipulation given them while under test. The Pintsch gas burners require occasional brushing and cleaning. The Frost gasoline system varies with the richness of the vapor burned, and requires about the same watchfulness while burning as an oil lamp, but does not fluctuate nearly so much in candle power. Even the electric lamps show great variation with slight alterations in current and with the age of the lamps. But no system of gas or electric lighting has any constantly variable element in it comparable with the condition of the wick in oil lamps.

The two gaslight systems tested are both defective in *distribution* of light. Much of the light is wasted on the carpet and the walls of the car without doing any sensible good. The Frost carbureter light is the most defective of the two in this respect, and the Pintsch light least so; but it is possible that the makers of both may get a useful hint from these diagrams, and by making slight changes in the form of the reflecting surfaces may get a much more *effective* light, distributed as in Fig. 72, from the same candle power and gas consumption.

We have spoken of the light thrown on the carpet or walls of the car as "wasted." This may be questioned on the ground that the light is reflected back into the car and becomes useful, but we believe it to be a substantially truthful expression.

A pretty accurate evidence of the real value of this reflected light may be obtained by comparison of the tests of the Belgian lamp with a shade and without one. Without a shade, the average semicircular candle power of the lower semicircle will be seen from Table IX. to have been (for 2 lamps) 31.82 c. p. Directly under the lamp the candle power was all most nothing, owing to the obscuring effect of the lamp body, and examination of the first column of Table IX. will make it clear that the probable mean candle power of the upper semicircle was 45 c. p. at least.

The shade used was an ordinary conical porcelain shade, which is a vastly better reflecting surface than the carpet or walls of the car, and had the effect to throw all the 45 c. p. of the upper semicircle downward, so far as effective reflection was possible. How much was added in this way to the total candle power of the lower semicircle? It was increased only from 31.82 to 45.47 c. p., a gain of 13.65 c. p., or less than 43%, only 30½% of the light in the upper semicircle being effectively reflected. If a porcelain shade cannot do more than this in the way of saving light by reflection, it is a perfectly reasonable assumption that hardly an eighth or tenth of the light is effectively reflected from the walls, and none at all from the floor.

It may be claimed that this otherwise lost light is of value, nevertheless, in giving a general air of brightness and cheerfulness to the car, but this also may well be questioned A universal glare is not pleasant in any room where one wishes to read. Plenty of light on the book and as little as possible (within limits) elsewhere is the preferable distribution.

THE CANDLE POWER OF ELECTRIC LAMPS.

The ordinary incandescent lamps used for car lighting are nominally of 16 candle power; practically, however, the light given off in different planes varies as greatly with them as with the lights described above. In order that comparisons may be easily made, we have drawn diagrams* (Fig. 76) of the candle power of various electric lamps on the same scale as the diagrams above.

It is evident from these diagrams that the electric light is among the best in distributing the light given out where it will do the most good. But the fact of greatest practical interest to railway managers who propose to try electric lighting is that the volume of light varies greatly with the kind of lamp used. Every one of the lamps whose candle power diagram is given in Fig. 76 is called by its makers a 16 candle power lamp; yet the actual volume of light is in some of these lamps double what it is in others; and the efficiency, or the amount of light given out for a given consumption of energy, varies also nearly one-half. Another point of interest is the variation in the light given off by the lamp in different vertical planes. In most of the lamps tested this variation is not great, but in the Weston lamp the light given off in the plane of the filament is only about half that given off in the plane at right angles to it. The difference in the available light is well shown by the diagram.

---

* The photometric measurements from which these diagrams are plotted were made by Messrs. H. M. HOBART and E. W. GANNETT in the Laboratory of the Massachusetts Institute of Technology, and were reported by WM. L. PUFFER in the *Technology Quarterly* for May, 1890.

It is of interest to compare the amount of light given out by these incandescent lamps with the light furnished by an electric arc lamp, shown by diagrams in Fig. 77. Necessarily these diagrams are plotted on a different scale from those preceding. If they were plotted on the same scale, a sheet would be required over 6 ft. wide, for the radial line representing the maximum candle power would be about 40 ins. long.

We are indebted for these arc light diagrams to a paper by Mr. LOUIS B. MARKS on "The Life and Efficiency of A c Light Carbons" (Trans. Am. Inst. Elec. Engrs., Vol VII.; p. 175). While the effect of the structure of the carbons upon the light was the chief object of the author's investigation, accurate photometric measurements of an arc light using the various carbons were necessary. The carbons used were from five different makers, designated A, B, C, D, E. Some of them were intended for high tension currents and others for low tension; and some of them were made by the "forcing" process (the plastic material being "squirted" through a die), while others were molded carbons.

For high tension carbons a current of 9 amperes was used, and the difference of potential between the lamp terminals was kept at 45 volts. Hence the electrical energy absorbed was 9 = 45 = 405 watts = 0.543 electrical HP. For low-tension carbons the current used was 21.5 amperes, with a drop in potential of 30 volts. Hence the energy absorbed was 21.5 = 30 =645 watts = 0.87 electrical HP. The average result in efficiency, with each kind of carbon, is given as follows:

Kind of carbon.	Watts per spherical c. p.
A. Molded, high tension	0.888
D. Forced, high tension	0.833
B. Unplated, molded, high tension	0.771
E. Molded, high tension	0.953
E. Forced, high tension	1.407
A. Forced, low tension	1.255
B. Molded, low tension	1.612

It is of especial interest to note that while in the incandescent lamp from 3 to 5 watts of electrical energy are absorbed for each candle power of light produced, the arc light generates a candle power with only ¾ to 1½ watts. In larger units, one horse power of electrical energy produces in the incandescent lamp 150 to 250 c. p.; and in the arc lamp, 500 to 1,000 c. p. This fact, that the electric current is used in the arc light with four times as great efficiency as in the incandescent light, gives good ground for hoping that some method may yet be devised whereby the efficiency of small electric lamps, suitable for interior lighting, will be much increased. When this is done, as we have before pointed out, electric car lighting will stand on quite a different footing from what it does to-day.

The Comparative Cost of Car Lighting Plants.

COMPARATIVE FIRST COST.

The preparation of any definite estimate of the cost of lighting cars by any system is necessarily a delicate matter. Most, if not all, of the items will vary considerably on different roads and in different sections of the country. An estimate which is even comparatively fair for one road or one part of the country will not be quite so for any other. To minimize these difficulties we have postponed the conclusion of these articles nearly three months, in order to gather all possible data. They cannot be wholly eliminated, and hence the tolerably accurate general average which we think we have reached, and give below, will require correction for the circumstances of each particular road.

The first cost of equipping cars with oil lamps varies between $115 and $225 per car, according to the make and style of lamp used. This provides for six double chandeliers, or their equivalent in more powerful single burners, and a closet light of little cost. It is a moderate estimate to take the cost of a good modern equipment at $175 per car, including all cans and storage and cleaning facilities off the car. Some lamp equipments, however, run up to $225 per car or more, for the above number of lights. The oil used, when actually of 300° F. fire test, is not much more dangerous than kindling wood to have about, and hence requires no special care or facilities for storage. Much of the oil actually in use however, is of much lower proof.

The yearly depreciation of such a plant is extremely difficult to estimate accurately. Mr. GEO. GIBBS, in his paper on car lighting,[*] estimates the depreciation at only 5%, but this in our judgment is far too small. The cases in which lamps are actually usable for more than 10 to 15 years are not more numerous than those in which they are condemned in less, as nearly as we can ascertain. Hence, 7% to 10% seems a fairer allowance. We assume 8%.

The cost of compressed oil gas plant, complete on the car, is thus stated to us by the Safety Car Heating and Lighting Co.:

1 receiver, 9 ft. 6 ins. × 20½ ins. diam., holding 220 cu. ft. at 10 atmospheres	$87
5 lamps (4-flame) having 2.75[†] cu. ft. per hour as a maximum, or 13¾ cu. ft. per hour in all, $25 each	125
Regulator, piping, etc	66
Labor applying	10
Total per car with one receiver	$288
Extra cost of additional receiver	87
Extra cost of more finely finished lamps at $30 each	25

The receivers are made of various sizes, varying from 6 ft. × 16½ ins. diam. to the size above given, which is the largest generally used. If more capacity is desired, two or even three receivers are used. If we assume the receivers to be able to deliver 10 to 11 times their cubic contents, or 220 to 242 cu. ft. of gas, there will be 16 to 17½ hours of supply at the maximum rate of combustion, for each receiver. As much as 22 hours per receiver is obtained with only four lamps, and no doubt this service, or more, may often be realized with five lamps in sleeping cars, where lights are turned down after certain hours; but it cannot be realized with full lighting power. It is, however, one of the admitted advantages of this system of lighting that lights can be turned down freely, which is possible neither with oil lamps nor carbureters, or that some lights can be extinguished and others left burning, which is not possible with the carbureter plant without running the risk that some lamps may give out without notice, as also another far greater risk, not generally recognized or understood, which will be pointed out in our concluding article on comparative safety. The Pintsch receivers may be considered, therefore, as furnishing 18 to 20 hours' supply.

---

[*] Eng. News, March 7-14, 1891.

[†] In the photometric tests (p. 200) these lamps burned 2.75 cu. ft. per hour, but 2.5 cu. ft. is probably a fairer average for actual service.

The Frost Carbureter Co., in some of their comparative statements, give the cost of compressed oil gas plant, complete on the car, at $317, with five lamps and one tank, against $288 to $313 by the statement above. To this the Frost company adds $100 per car to allow for the cost of gas works.

Mr. Geo. Gibbs, of the Chicago, Milwaukee & St. Paul, in his paper before referred to, gives the cost of Pintsch plant complete on the car at $370.25, with only four 4-flame lamps and a closet lamp. To this he adds the large sum of $181.75 as the pro rata of each car for fixed plant. Both of these estimates, but especially the latter, were objected to by the Pintsch company; and Mr. Gibbs stated in explanation that his estimate was only for one particular road, on the assumption that the full capacity of the gas plants was not utilized.

The Pintsch company claim, however, that a charge of even $100 per car for fixed gas works is unfairly high for purposes of comparison, though they admit it may at times reach that figure or more. Of course this must always be a more or less indeterminate item, but the ultimate tendency must be to supply about as many cars from each plant as its capacity permits. Even under these latter circumstances the cost of fixed gas-making plant per car will vary greatly, as follows:

Gas plant supply'g	Capacity cu. ft. per day.	Cost of Apparatus.	 B'ld'g.	Total cost.	Cost per car.
500 cars	24,000	$11,000	$4,500	$15,500	$31
200 "	10,800	9,500	4,100	13,600	68
100 "	6,000	7,500	3,000	10,500	105

The costs above given are the same as those given by Mr. Gibbs.*

In order to insure a full supply where needed to

---

* The Safety Car Heating and Lighting Co. furnishes us the following revised list of the gas works which they are now prepared to furnish and erect, giving the capacity in cubic feet per day and number of cars they will supply, the cost of apparatus, cost of building, total cost erected, and cost per car erected, stating that since they furnished the above data to Mr. Gibbs they have arranged for works of smaller capacity than those specified to him.

Gas plant supplying.	Capacity cubic feet per day.	Cost of Apparatus.	 Building.	Total cost.	Cost per car.
60 Cars.	3,000	$3,900	$1,500	$5,400	$90
150 "	8,000	5,100	1,600	6,700	45
200 "	10,800	7,500	3,000	10,500	52
360 "	18,000	10,400	4,100	14,500	40
500 "	24,000	11,180	4,500	15,680	32
900 "	45,000	18,500	7,500	26,000	29

only 466 cars, however, Mr. GIBBS allowed for one 500-car plant, two 200-car plants and four 100-car plants, or seven in all, thus providing capacity for the potential supply of 1,300 cars, or nearly three times the actual number to be supplied. This plant was estimated to cost $84,700, or $181.75 per car actually supplied, as above stated. However prudent it might be to do this in making an estimate of the immediate future for some one road, it is obviously too high for the purpose of this investigation, which is to determine what system has greatest merit for general use. The cost per car potentially supplied by Mr. GIBBS' plant was $65. We shall, therefore, assume $100 per car as a reasonable general estimate for this item. Under present conditions this is low, but it would probably prove too high after the system was once in general use.*

The Erie is now supplying some 550 cars from a single works costing $17,000, or about $31 per car. The above allowance would permit them to expend $149,000 in all for supplying less than three times as many passenger cars, 1,490, which is all they own, to which should be added a large further sum for the sleepers supplied. The New York Central is also supplying all its through cars from a single works. The cars make the round trip to St. Louis or Chicago with one charging of two to three tanks.

It is to be remembered that it is by no means necessary to erect works at every point where it may be necessary to supply cars. Tank cars carrying three large tanks, holding some 10,500 cu. ft. of gas at 12 atmospheres, will supply 840 car-hours of maximum combustion, equal to about 280 car-days, before they are exhausted. Details as to current practice in this respect were given on p. 16.

---

* Mr GEORGE GIBBS, who has done us the favor to examine proofs of this article before publication, advises us that he considers this a "very fair general average."

The annual depreciation of the compressed gas plant on a car, while impossible to estimate exactly, should probably be estimated lower than for any other form of lighting, because it is the simplest of all, consisting only of a supply tank with connected regulator, gas piping and gas burners. The depreciation of the tanks, gas pipes and gas burners will be almost nil; the regulator has been shown by experience to be an exceedingly durable device; the ornamental and reflecting parts of the lamps are alone likely to suffer much with time. The gas making plant, however, depreciates more rapidly. We believe a depreciation allowance of 5% per annum for the car plant and 10% for the fixed gas-making plant to be a closely approximate estimate.*

The Frost carbureter plant requires practically no plant off the car. The company claims with truth that a metal shed costing $200 will store 80 to 111 two-gallon cans of gasoline, which by sufficiently frequent recharging will be a sufficient store for supplying 100 cars. The expense for plant off the car is so small that it may be neglected.

The cost of the plant on the car is thus given by the company:

---

* We are informed that with compressed oil gas, as handled in the Pintsch plant, no liquid hydrocarbons are deposited in the distributing pipes or on the car, as happens with some coal gas plants The difference is due to difference of process more than to difference in the gas.

Cost of air tank, regulators, safety valves, closet and tank needle valves, copper tubing for air supply, deck check and safety valves and combination dust guard and check valve	$117.95
Cost of each carbureter and lamp complete with copper tubing and brass tee to connect with deck pipe, $77.86 each—for five lamps	389.30
	507.25
To this add labor applying, say	15 00
Total per car	$522.25

A statement furnished by the Pennsylvania road of somewhat earlier date, shows a somewhat smaller cost and is in more detail, as follows:

Tank, 10 ft. 3 ins × 16 ins		$25.00
Combination regulator and safety valve		20 00
Closet needle valve		2 00
Tank needle valve		2.75
Combination dust guard and check valve		3.00
Deck check valve		1.55
Deck safety valve		1.48
Brass unions, ½ in., 4 at 45 cts. each		1.80
Brass Ells, ½ in., ⅛ in		,25
Brass Ells, ½ in., 4 at 21½ cts. each		.85
Copper tubing to suit length of car		15.00
Total for parts independent of lamps		73.68
Each lamp	$30.00	
Carbureter for same, complete	50.00	
Brass tee, ½ in. × ⅛ in	.25	
Total per lamp	80.25	
Total for five lamps		401.25
Total cost plant complete for 1 car. 5 lamps		474.93
To this add labor applying, say		15.00
Total cost on car		$489.93

This shows a cost some $33 less than the company's figures, though it is for a somewhat more costly plant, the regulator and other parts having been somewhat modified and cheapened since the statement was made up, as explained on pp. 32-42.

The difference may be due in part to the fact that the Pennsylvania supplied a good many parts from its own shops. We take the company's figures.

The annual rate of depreciation of the Frost carbureter plant may be taken as less than that of oil lamps and more than that of compressed gas car plant. With respect to the tank, reducing valve, piping and (in some degree) the burner, the gasoline and fixed gas plants stand on an equality; but there are the carbureters, check valves, dust guards, safety valves and indicators, which, as a whole, are more subject to deterioration than the parts of the plant which are common to all gas-lighting systems, while the flame of the lamp itself does not remain constant after once lighting, but requires regulation from time to time as the temperature of the plant varies, thus tending to more rapid depreciation.*

On the other hand the evidence is very strong that the carbureter proper, including its interior wicking, is very durable. We have seen pieces of carbureters, which had been in use for many years, cut open to show their condition, which seemed to be for all practical purposes as good as new. Keeping all circumstances in view, we think that an annual depreciation allowance of 7%, against 5% and 10% with compressed gas plant, and 8% with oil lamps, is as relatively fair an estimate as can be made.

---

*An officer who has had considerable practical experience with the system writes us: "The sheet iron and pasteboard casing of the carbureters is much exposed to cutting by cinders, etc., and must be renewed very often at considerable expense."

On this basis, and charging interest on first cost at 6%, which is as low a rate as most railways care to earn on investments, we have the following comparison of the three plants in question:*

System.	Cost new per car.	Annual interest.	Depre-c'n,	Total p. c.	First cost charges per year.
Oil lamps, 6 double chandeliers......	$175	6%	8%	14%	$24.50
Pintsch gas, 5 lamps, (4-burner)	313 100	6%	5% 10%	11% 16%	34.43 16.00
Carburetors, 5 lamps............	522	6%	7%	13%	67.86

These first cost charges are to be added to the annual operating cost to get the total cost per year.

---

* Other estimates, which we do not consider as correct as the above, after careful comparison have been as follows.

Estimate of GEO. GIBBS, C. M. & St. P. R. R.:

Oil lamps.........	$167	5%	5%	10%	$16.70
Pintsch gas in car. Pintsch gas fixed.	370 182	5%	5% 10%	10% 15%	37.00 27.30
Carbureters......	536	5%	10%	15%	80.40

The following is from estimate prepared some years ago for the Baltimore & Ohio R. R., when oil lamps were generally more ornate than now, and the other two plants quite different. The estimate is also for a less amount of light:

Oil lamps...	$203	Other items above not estimated.
Pintsch gas in car. Pintsch gas fixed.	228 150	
Carbureters......	369	

The following comparative estimate is one put forward by the Frost Carbureter Co.:

6 double lamps ...	$210	Other items not estimated.
Pintsch gas in car. Pintsch gas fixed.	317 100	
Carbureters.......	507.25	

This last estimate actually allows $105 for half the number of oil lamps, but the estimate is doubled to make it correspond in number of lights with the other tables.

The comparative operating cost we will now proceed to estimate.

COMPARATIVE COST OF OPERATING.

It is noticeable that the three systems of lighting in question all use an illuminant derived by distillation from the same substance, crude petroleum. The Pintsch oil gas system takes this crude oil and subjects it in bulk to a destructive distillation, by which it is nearly all converted into fixed gas of very high illuminating power,* having the further valuable property that this gas possesses few components which are readily liquefied by pressure, as does coal gas, so that the oil gas can, while the coal gas cannot, be compressed to 10 or 12 atmospheres without serious loss of illuminating power. When compressed to 10 atmospheres coal gas loses about 50% of its illuminating power, by liquefaction of certain of its elements; oil gas loses only 7.4%. (See p. 101).

To produce the other two illuminants the crude petroleum is subjected to a "fractional distillation" process by which several different illuminants are produced (See p. 4, *et seq.*), the two most abundant being ordinary household kerosene (about 70% of the whole †) and the various naphthas, benzines and heavier gasolines (16.3% of the whole). The parts lighter than the ordinary gasoline (0.7% only of the whole) constitute the light gasoline of 88° Beaumé boiling at 110° F., which is required for carbureters.‡ On the other hand, the products heavier than household kerosene consist of "mineral sperm oil" (about 10% of the whole) of 300° F. fire test and boiling at 425° F., which is (supposed to be) used for car lamps, and about 5% of lubricating oil, paraffine wax and solid residuum.

---

* The candle power of gas, unless otherwise stated, is always understood to be that of an Argand burner, burning 5 cu. ft. per hour. Ordinary city gas runs from 16 c. p. to (rarely) 20 c. p. or more; i. e., from 4 to 5 c. p. hours per cubic foot of gas. Oil gas, on the other hand, runs up to 60 or 80 c. p. or more i. e., to 12 to 16 c. p. hours per cubic foot of gas, being from 3 to 5 or more times as effective as coal gas.

† The Treasury Department has carried for many years at the foot of its petroleum statistical reports a statement that good authorities estimate that 100 gallons of

Looking at the problem of comparative cost abstractly, therefore, to get an idea of permanent tendencies rather than momentary market conditions, it will be seen that the same very cheap illuminant, crude petroleum (worth 2 to 6 cts. per gallon) furnishes an extremely small quantity (7 bbls. in 1,000) of light gasoline suitable for carbureters, a quantity 14 times larger (100 bbls. in 1,000) of burning oil suitable for car lamps, and is all convertible into oil gas for compressed gas lighting. With the present mean annual product of 30,000,000 bbls. of crude petroleum, only 189,000 bbls. of 88° gasoline can be produced, and 2,700,000 bbls. of mineral sperm.

Mineral sperm being chiefly used for car lighting, and a few like uses where a high degree of safety is

---

crude petroleum will furnish 76 gallons of illuminating oil, 12 gallons of the various naphthas and gasolines, 3 gallons of lubricating oil and 9 gallons of residuum.

‡ We neglect in this summary the chemical curiosity rhigoline, boiling at 65° F., which may be obtained in insignificant quantities by careful manipulation of the lighter distillates, as may also, in fact, still lighter distillates boiling at 1° and 38° F., by sufficiently delicate chemical processes. (See p. 7).

required, the supply may be considered equal to all probable demands, as also, of course, the supply of crude petroleum for gas making. The 88° gasoline, however, is what may be called a "fancy" product, suitable only for certain special uses, and a mere waste product if not applied to those uses, as was for many years the case; but liable to rise in price if its use extends, since the supply is strictly limited, especially as it is of so volatile a nature that from 15% to 20% must be allowed as wastage, between its distillation and its final use.*

Allowing the entire passenger stock of the country to average three hours per day of car lighting (1½ hours in summer, 4½ hours in winter) and the entire passenger stock of the United States and Canada to consist of 40,000 cars, we have the following estimates of the total quantity of illuminant required per year to light this equipment by either of these three systems:

---

*A Baltimore oil refiner stated to us in regard to the supply of the various naphthas, that the crude oil, before being supplied to customers for fuel purposes, was put into a still and the naphtha distilled and collected. For this reason the supply of the naphthas is much increased and it must still further increase with the consumption of "Lima oil." This oil is being used very largely for fuel purposes now, and the production is as yet unlimited and increasing so rapidly that the pipe lines are said to be unable to meet orders.

This Lima oil is used but little as yet for the manufacture of burning oils, as it is difficult to refine and contains comparatively only a small quantity of burning oils. For this reason it is not (we are informed) included in the statements of oil production. This fact has an important bearing on the above estimate, though it is impossible to allow for it accurately, any more than for the large and increasing use of the lighter gasolines for other than car lighting purposes. Inquiry at the main offices of the Standard Oil Co., in New York, shows, however, that while the production of naphtha is now very great, gasoline is produced only in limited quantities. For the past six years there has been no great fluctuation in price of 88° gasoline, and it can now be bought in bulk in New York at 13 to 14 cts. against about 11 cts. for 86° gasoline and proportionately less for the benzines and naphthas. The higher officials state their belief that if the demand warranted it the production of the lighter gasolines could be greatly increased, perhaps enough to light all the passenger cars on the continent without much if any increase of price.

1. Mineral Sperm Oil:—The Belgian lamp, which gave the best test in respect to consumption of oil per candle power hour, averaged as nearly as may be 1¾ oz. per lamp hour, or 1¾ × 12 × 3 = 63 oz. = 0.576 gallon for three hours' burning of a 12-lamp car.† Calling this in round numbers 0.6 gallon per car day (= 4.8 gallons for 24 hours burning of 12 lamps) this requires 219 gallons, or 5.215 bbls., per year per car, or 208,600 bbls. per year for 40,000 cars, the " visible supply " being 2,700,000 bbls.

2. Compressed Oil Gas:—"A fairly good yield of the gas, which can be obtained in every day practice, is 70 to 85 cu. ft. per gallon of crude oil" according to one statement based upon long English experience; according to another statement 70 to 90 cu. ft. is obtained in England. American experience runs lower, however, varying between 45 and 70 cu. ft. Full details were given on pages 100, *et seq.*, showing that about 60 cu. ft. of gas from each gallon, or 2,520 cu. ft. per bbl. of crude oil, is a fair average of good American practice. The Erie works, one of the oldest in the country, is now regularly realizing about 70 cu. ft. per gallon.

Each of the five 4-flame lamps which have been assigned to each car above, will burn when giving their maximum light 2.75 cu. ft. each per hour, or 13.75 cu.

ft. per hour in all, equal to 41.25 cu. ft. per car per day, or 15,056.25 cu. ft. per car per year. To produce this quantity requires, at 2,520 cu. ft. per bbl. of oil, a little less than 6 bbls. of oil. For 40,000 cars, this means the consumption of 240,000 bbls. of crude oil per year, the "visible supply" being 30,000,000 bbls.

3. Frost Carbureters:—This plant works in two ways, as explained in detail on pp. 75–96.

Method 1. According to its theory of construction, by merely charging air with such amount of gasoline vapor as it can take up when both air and gasoline are below the boiling point of the latter (110° F.), and:

Method 2. By heating the gasoline, in part or whole, to or above its boiling point, and thus turning it gradually into steam, which may or may not mix with a certain amount of air on its way to the burner, according to the amount of pressure created by the gasoline steam.

We have no experimental evidence that the gasoline plant ever works according to Method 1 for any length of time. It is quite certain that it does not work so, but by Method 2, in the form of the plant which was supplied and erected for our tests by the manufacturers, and which has been and (so far as we are advised) is now almost exclusively used on all roads using the plant except the Pennsylvania. Indeed this form was in use for a time on quite a number of cars on the latter road, until the attention of its officers was attracted to its real nature. It is certain that the Pennsylvania form of the plant will not direct nearly so much heat around the carbureter as that used on other roads, and remembering also the evidence of the photometric tests, which show that much less light is given off by the Pennsylvania plant than by the newer form (compare Figs 71, 72, and Fig 70), we judge that the Pennsylvania plant as originally devised and as now exclusively used on that road heats but little of the gasoline above the boiling point, or perhaps none at all.

We can only consider accurately, however, the plant which we have experimentally tested and which is still in most general use, giving it credit for the extra light obtained, and extra consumption of gasoline. For comparative purposes as indicating what might possibly be proven for the plant if tests were made under Method 1, in which all boiling of the gasoline was prevented, we may assume that with only half the consumption of gasoline half the candle power might be shown. This is making a favorable assumption for the plant, however, as mixing half as much gasoline with a given quantity of air would more than halve the photometric power of the gas. Under Method 1 only 40% of gasoline by weight, at most, can be taken up by air (See p. 10). Under Method 2 the gasoline used averaged 174% of the weight of the air used (See p. 19) in the tests from which we derive our photometric records; *i. e.*, 1.92 gallons of oil (166 oz.) burned for 41 hours and was mixed with 72 cu. ft. (88 oz.) of air in that time.

At this latter rate the five lamps assumed for each car would burn 9.6 gallons in 41 hours, to which 15% should be added for wastage, making 11 gallons in 41 hours. In a year the lamps will burn 365 × 3 = 1,095 hours, whence 293.7 gallons, or 7 bbls. of gasoline per year will be required to light one car. For 40,000 cars this becomes 280,000 bbls., the "visible supply" being 189,000 bbls. If we assume, as above, that under Method 1 half this consumption will suffice for half as much light, obtained without boiling the gasoline, we still need 140,000 bbls. per year, or nearly all the present visible supply, assuming it to be all used for this purpose.

This supply is, on the one hand, capable of large increase (perhaps to double or more its present volume) as demand increases, and, on the other hand, is even now heavily encroached upon to supply fixed gas plants and other demands of the arts. The balance must be struck according to one's individual judgment, all that is certain being that the supply appears to be unequal to any very large increase of present demands, without increase of price. To some extent increase has already taken place. When the first experiments in gasoline car lighting began, the lighter gasolines were almost a waste product. They are now the dearest of the commercial petroleum products.*

Summarizing the above, and adding from p. 200, the photometric efficiency in candle powers determined for the several plants, we have found that to light 40,000 cars for one year by each of the above methods requires 208,000 bbls. of mineral sperm oil for lamps, giving 273 circular c. p. per car (from which about 20% should be deducted for imperfect trimming of wick, etc., in service); 240,000 bbls of crude oil for making gas, giving 202⅛ c. p. per car, 290,000 bbls of 88° gasoline for carbureters operated under Method 2, and giving 395⅛ c. p. per car, 140,000 bbls of 88° gasoline for carbureters operated under Method 1 and giving 197.8 c. p. per car.*

---

* Mr. W. B. D. PENNIMAN writes us in regard to this paragraph: "It was a waste product at the refineries, but not in the market. In my experience in the last three or four years it has gone down in price, and we are now paying 9¾ cts. for it, delivered as we please."

The cost of these illuminants we take at 9.2 cts. per gallon for mineral sperm oil, 15 cts. per gallon for 88° B. gasoline, and about 4 cts. per gallon for crude petroleum, the latter, however, being a figure which does not directly concern us, as it is included in the cost of the gas per M. cu. ft., which latter we have yet to determine.†

On pages 97–131 we gave such full details as

---

*Mr. **Geo. Gibbs** writes us in regard to amount of lights "I think your figures for the Frost system too high for average running. I find all forms of their lamps give very irregular results, depending upon condition of lamps and charge in carbureters." While this may be true in some degree, however, we do not feel justified in making any deduction from our photographic records for the carbureters, as we do for the oil lamps, where its propriety is indisputable.

†Some further information as to cost of Pintsch compressed gas is given in the discussion of a very recent paper on "Railway Train Lighting," (chiefly referring to electric lighting) by Mr. **Wm. Langdon** [Proc. Inst. C. E., vol. CVI., 1890–91, p. 154] Mr. J. P. **Rickman** (Gt. No. Ry.) stated that on the Northeastern Ry. the cost of oil gas from works supplying 600 coaches [perhaps equivalent in demand for light to 100 of our cars.—Ed.] was 8s. 6d. ($2.05) per M. cu. ft.. His own company supplied the North British at $2 per M cu. ft., out of which "they made just enough to pay their way." The expense of filling "meant a few laborers and porters at $5 per week, so that the cost was a mere bagatelle."

to the cost of manufacturing the gas at 13 different works, that we will now merely summarize and compare the final aggregates of those details. It is to be remembered that we have already allowed 15% on the first cost of the plant, or $15 per car per year for interest and depreciation of the fixed plant only, which latter items we do not need to consider again as part of the cost of producing gas. The total yearly consumption of gas per car being about 15,056 cu. ft., as above determined, this allowance of $15 is $1 per M. cu. ft. for interest and depreciation; the allowances made for these items in the statements on page 102, *et seq.*, having been 72½, 56, 27, 20 and 28 cts. respectively, or all much less than we allow.

The cost for oil, fuel, labor, compressing, running repairs to plants and delivery in car receivers was thus reported in the successive statements.

		Cost per M. ft.
HUNTER'S Inst. C. E. paper (p. 99)		$1.58
AYRES' Inst. C. E. paper (read April 10, 1888)		1.32@ 3.84
Mean experience of six English railway systems		2.27⅛
One American works, producing 3,000 M. ft. per year (but obtaining only 46 cu. ft. per gallon of oil)		3.65
Another do. in same city, producing 4,000 M. ft. per year.		1.83
N. Y. C. & H. R. R. R. plant, operated by Pintsch Co. and producing 9,000 M. ft. per year (including tankage of gas to Grand Central Station)		2.35
Erie plant at Jersey City, producing 6,500 M. ft. per year	1st 6 mos.	1.78
	2d 6 mos.	1.81

From this the assumption seems to us warranted that $2.20 per M. cu. ft. represents a fair general average of the cost of the gas in the tanks, including a certain amount of transportation in tank cars. On many favorably situated roads the cost may fall considerably below this, down to perhaps $1.75 per M. ft.; on others, unfavorably situated as to the supply of coal and oil and amount produced, the cost may rise to $4 or over for a time. When the gas is purchased in small quantities the usual price is $5, which either includes a good-sized profit or the loss from running new works below their proper capacity.*

The varying cost of the crude oil alone makes a considerable difference in the cost of the gas. It can, of course, be obtained most cheaply when a pipe line is accessible. With crude oil costing per gallon:

2 cts. 3 cts. 4 cts. 5 cts. 6 cts.

the cost for oil only of gas per M. cu. ft. of gas, at 60 cu. ft. of gas per gallon of oil, will be:

33 cts. 50 cts. 67 cts. 83 cts. $1.00

The actual reported cost of the oil only per M. cu. ft. of gas varies in the American works from 33 cts. to $1.20.

We can now prepare the following summary of the daily cost of illuminant per car by the various systems. For the visual units we take the mean shown by Figs. 74, 75.

---

* There are considerable variations in the price of oil and gasoline, according to location and the circumstances. Oil ranges in price from 7 cts. to (for small lots) 15 cts. Gasoline of 88° B. can be and is bought for delivery at points near refineries as low as 9¾ cts., as shown by a previous note. We consider the effect of these differences below, but regard the prices given as the fairest general averages. The Railway Lighting & Manufacturing Co. (Frost system) itself uses 15 cts. per gallon in its circulars for estimating the cost of lighting by its system; but Mr. W.B. D. PENNIMAN writes us that he is quite certain that it can be bought for 11 cts. by any large consumer.

	Consumpti'n per day of 3 hours.	Cost per gallon.	Cost per day of 3 h'r's.	Circular candle powr	Visual units
	galls.	cts.	cts.	c. p.	
Car lighted with mineral sperm oil...............	0.6	9.2	5.52	218.*	37.9
Pintsch comp. gas.	cu. ft. 41.25	per cu. ft. 0.22	9.075	202.5	37.5
Frost system:					
1. Gasoline and air	galls. 0.4	cts. 15.0	6.00	197.8	39.1
2. Gasoline steam	0.8	15.0	12.00	395.5	78.3

*273 c. p. less 20% or 55 c. p. = 218 c. p.

It will be seen from the last column above that all three of these plants provide a very brilliant light. The "visual unit," as defined on p. 201 is one effective candle power at a distance of 4.5 ft. sending rays perpendicularly upon a surface at an angle of 45° with the horizontal. With some 39 candles burning at this distance, as defined, the passenger would have all the light which he could reasonably require for reading the finest print.

There remains but a single element to be determined before we can make a final summary of the comparative cost of lighting cars by oil, oil gas and gasoline gas, viz., the cost for attendance and minor supplies, including chimneys, shades and globes, new burners when necessary, and cleaning, filling and adjusting lamps. It is in the nature of things all but impossible to make an accurate estimate of this item for any system of lighting on any road, but as an average between many different estimates we believe the following to be substantially accurate, erring, if at all, in favor of oil lamps and (in much less degree) carbureters, by estimating their cost for this item too low.*

Cost of cleaning, attendance, glass breakages, small repairs, etc.

	Per year.	Per day.
Oil, lamps, 12 per car	$18.25	5 cts.
Pintsch gas, 5 lamps per car	7.30	2 "
Frost carbureters, 5 lamps per car	10.95	3 "

There is still another expense connected with the use of oil lamps, that of injury from spilled oil for which some allowance should be made, though we do not make any because it is impossible to estimate it exactly. It appears from an abstract of "Accidents in the Railway Mail Service," published in ENGINEERING NEWS, Jan. 30, 1892, that 2% yearly (1.97%) of the postal cars in service have oil spilled from lamps as an effect of train accidents to a sufficient extent to damage the mails more or less. The instances in which oil is thus spilled from carelessness or structural defects, without any train accident, might easily be still more numerous. An allowance of $10 per car per year for this cause might not be unreasonable. In sleeping, parlor and other carpeted cars the loss from this cause is generally stated at a much higher figure.

---

* Mr. Geo. Gibbs, in his paper before referred to, allows 3.18, 1.65 and 3.35 cts. per day of three hours for care of oil, gas and carbureters respectively, instead of 5, 2 and 3 cts. respectively which we have adopted. He states that this is in each case based upon the actual experience of his road, which as respects oil lamps was for a stock of 466 passenger cars, but as respects the other two was for so small a number of cars as to be open to some suspicion, though based upon exact records. His estimate for oil lamps includes the storekeepers' charges for burners, chimneys, shades and small supplies, while the attendance charges were carefully deducted from the payrolls, with allowance for time of men partially employed so far as possible. These figures seemed so very low, however, that we have slightly increased them as above, and we believe them still to be too low. Our guess would be that 10, 4 and 6 cts. would come nearer to the truth, all items considered. Some official German estimates of the cost of cleaning lamps show that oil lamps and compressed gas compare as to this item in the ratio of $3.30 to 85 cts., and in all items, per lamp hour, in the ratio of 0.70 cts. to 0.15 or 0.19 cts. A variety of other German estimates of this kind which we have examined show about this ratio. One shows the yearly cost of attending a gas lamp to be only 36½ cts., against $4.02 for oil lamps. The conditions of service are so different in Germany that direct use of these statistics for estimating purposes is difficult, but relatively they should be about fair.

We can now make (Table XII.) the following summary of the TOTAL YEARLY COST OF LIGHTING A CAR, including all items of every nature and kind whatsoever except that of injuries from spilling oil. We subjoin to our table a rearrangement in the same form of the estimate of Mr. GEO. GIBBS, Mechanical Engineer, Chicago, Milwaukee & St. Paul Ry., in order to facilitate comparison. We consider his estimate far too low for oil lamps, and somewhat too high for Frost carbureters.*

Change the figures set forth in the large accompanying table as we may, and keep within the bounds of reason, the comparative result seems to come out much the same. The table above is in such form as to make it easy to study the effect of any change. The first cost cannot be materially modified. The depreciation allowances cannot rationally be modified more than 2 to 3% either way, and such change would have little effect upon the comparison. The amount of light, and with it the consumption of oil or gas, cannot be decreased

---

* The following estimate was prepared some years ago for the Baltimore & Ohio road. Several important conditions have changed since then, and for that and other reasons it is not now considered accurate in detail, but we

---

have requested permission to give it for completeness, and as an entirely independent estimate.

	Oil.	Comp. gas.		Carb'ters.
No. of cars taken as a basis	100	100		100
Cost of permanent plant	None	$15,000		None
No. of lamps per car	3	3-6 flame		4 Excelsior
Average C. P. for 10 hours	78 c. p.	130 c. p.		104 c. p.
No. of burning hours bet. refillings	10 hours	25—49 hours		120 hours
Cost per car of plant on do.	$203	$228	$329	$368.76
" of operating per hour.	4 cts.	2 cts.	2 cts.	1½ cts.
Total cost of lighting 100 cars 100 hours	$400	$200	$200	$150
Total cost of equipping 100 cars	$20.300	$37,800	$47,400	$36,876
Taking 3 hours per night as an average burning, cost of lighting one car per year = 1,095 hours	$43.80	$21.90	$21.90	$16.42
If we add to this operating cost our assumed interest and depreciation allowances of	14%	11 and 16%		13%
Or in money, per car	$28.42	$49.08	$60.19	$47.94
We have as the total cost per year for lighting one car one year	$72.22	$70.98	$82.09	$64.36

If these estimates were corrected to be on a basis of equal light, they would show oil to be the most expensive of the three and compressed gas the cheapest. If we assume that 50% of the above total cost varies directly with the volume of light, which is rudely approximate, the cost per year per car of each mode of lighting would be:

	Oil.	Comp. gas.		Carb'ters.
For 130 c. p.	$96.80	$70.98	$82.09	$72.40
For 200 c. p.	$128.70	$90.32	$105.19	$94.06

more than 25% and have sufficient light. About 150 c. p. per car is now considered essential, and 200 c. p. is necessary to give what is now considered first-rate lighting. The three systems run so close to 200 c. p. each, as above tabulated, that for all practical purposes they may be considered as giving equal light.

Attendance and small supplies is a more dubious and variable element. Mr. T. N. Ely, Gen. Supt. M. P. Penna. R. R., informs us that he has recently had occasion to make a very careful investigation of both systems, as to which it would be best for them to use, which fully convinces him, among other things, that the cost of care, cleaning, regulating and so forth of a compressed gas system would much exceed that of carbureters. We can not adopt this conclusion as generally applicable, but it is an opinion entitled to great weight. Adopting it tentatively, by transposing the estimates for this item, so as to make this item cost 50% more with compressed gas than with carbureters instead of vice versa, we have:

	Oil lamps.	Gas.	Carbureters.
Instead of the above totals...............	$62.90	$90.85	$100.74
		deduct 7.30	deduct 10.95
		and add 10.95	and add 7.30
Total, with attendance charges reversed....... .	$62.90	$94.50	$97.06

If our estimates for cleaning and attendance err at all, in our judgment, they err in being all too small, rather than in their ratio to each other. Increasing them to 10, 4 and 6 cts. per day per car instead of half those figures,

We add to our estimate above	$18.25	$7.30	$10.95
Making the total.....	$81.15	$98.15	$111.66

Or, reversing the charge for the gas and carbureter systems, according to Mr. Ely's suggestion, we have:

	$81.15	$105.45	$104.36

If we assume gasoline to cost 11 instead of 15 cts. per gallon, it will deduct $5.84 from the cost per year per car by that system. If we change the estimated price of gas either way from $2.20 per M. cu. ft. it will add or deduct about $1.50 per year for each 10 cts. per M. ft. of change from that figure.

With all these figures before him, the reader can take his choice or make new figures of his own. It is to be remembered, however, that the economy of the compressed gas system varies, far more than either of the other systems, with the number of cars equipped for it, and hence on its first introduction the compressed gas system labors under a disadvantage from which the other two are free. The above estimate is intended to exhibit the cost when all or nearly all the cars of a considerable road are using it, not when it is first applied to a few cars.

In the last noted feature of the above comparative estimate, morever, "Hours of light between charging," the Frost carbureter plant has a decided balance in its favor, and if there is really any important gain in operating convenience from this difference, some money value should be assigned to it. We make no such assignment because we are unable to perceive that the difference is of moment, when the comparative ease of charging is taken into account. Charging with compressed gas is a very simple, quick and (with ordinary care) safe operation. The Pennsylvania Railroad has always charged its passenger cars with coal gas, when required, while cars were in transit and stopping at the stations. Charging carbureters with gasoline is a much longer operation, and to avoid possible accidents from spilling gasoline it is required to be done by daylight, outside of station buildings, and while cars are out of service. The frequent fillings required for oil lamps, with their attendant dirt and smell, are undoubtedly one of the evils of that system of lighting, but as respects the two gas lighting systems, it seems to us that between coupling on a hose for a few moments at the end of each round trip, and going through the more elaborate process of charging carbureters every fourth or fifth trip, there is little to choose.

As for the cost of lighting cars by electricity, we gave such full details on pp. 180–193 that we need not go over the ground again. It is as yet not a feasible system for general use, yet its cost is not so excessive as to be unreasonable for trains "de luxe," as they are called abroad. Its first cost varies from $400 per car upward, according to the number of cars per train, and the average cost per c. p. hour of all the eight different records given, has been 0.081 ct. per c. p. hour. This has been for the most part on an all-night service, whereas we have assumed only 3 hours per day (4½ hours in winter; 1½ hours in summer) to be the average period of lighting for all the cars on any road. But this average is made up by some of the cars running all night, and others only in day time, so that for merely approximate comparative purposes we may take the above cost per candle power hour and multiply it by 3 (hours) × 365 (days) × 200 (average candle power per car heretofore assumed) giving $177.39 for the average cost per car per year of electrically lighting all cars, to which is to be added at least $40 per year (10%) for interest on first cost and depreciation, making $237.39 per car per year in all, as against less than half that sum for oil or gas. The gap is great, but it is quite likely to be bridged.

The Comparative Safety of Various Car-Lighting Plants.

Safety and danger are relative terms. In a literal sense there is hardly a known substance or process so safe as not to be at times dangerous, or so dangerous as not to be at times safe. A carpet is by general admission a tolerably safe and harmless article for general use; yet it has been put on record that in France there were 14 persons who suffered death in staying at home and there tripping over carpets to 10 killed in railway accidents.*

On the other hand, dynamite is by general admission a highly dangerous substance for general use; yet it is on record that when it was first introduced it was claimed to be as safe and harmless as corn meal or sugar to handle or to transport, except when in the presence of exploders. Elaborate experiments were made tending to show this, and which in a sense did show it, in order to persuade the railways that no restrictions were needed on its transportation. It was thrown in large quantities on bonfires, and burned harmlessly. Boxes of it were thrown from the top of the Palisades, falling some 200 or 300 ft., and stones then thrown down upon them. It was placed upon wooden floors and pounded, and small quantities were even placed upon iron and struck with a hammer to show that though small detonations would occur under the hammer, they were not of sufficient force to explode the rest of the mass lying alongside. These tests were also made with frozen dynamite, and considerable quantities were frozen and thawed repeatedly to show that there was "no danger" in that.

---

*"Railroad Accidents," by Chas. Francis Adams, p. 242.

As a consequence, many of the railways were convinced, and transportation at low rates (for dynamite) was granted. It was but a very short time thereafter before a series of frightful disasters began to demonstrate the inconclusiveness of these experiments. Some of these accidents occurred under circumstances which differed from the prior tests only in result—some of them from causes or circumstances which had not been anticipated. The privileges previously granted were speedily withdrawn and have not been renewed to this day. No railway engaged in general traffic will now transport dynamite on any terms, if it knows it.

This proscription usually extends even to construction trains; but an explosion occurred May 19, 1891, on the New York Central & Hudson River R. R. of some dynamite which was being carried on a flat car in a construction train, killing 19 workmen and injuring others. The carriage of the dynamite on the train was claimed to be contrary to orders.

This record as to dynamite illustrates one truth which it is important to keep in mind. Laboratory tests of all kinds which attempt to prove that any substance or process otherwise open to suspicion is "not dangerous" have that fatal element of inconclusiveness about them which attends all efforts to prove a negative. What they set out to prove, and have often been too carelessly assumed to prove, is that such substance or process is under no circumstances dangerous, or unreasonably or exceptionally so. What they actually do prove is merely that under the specific conditions tried, and in the specific hands which tried them, they are or are not thus dangerous. The distinction is a broad one.

Nevertheless, though every process is at times safe, and each is at times dangerous, we are all conscious that there is a foundation of truth in the popular practice of roughly dividing all substances and processes into two great classes, "safe" and "dangerous," according as there is a preponderating tendency to safety or danger. We take it that the distinction is a just one, analogous to that which is drawn in mechanics between stable and unstable equilibrium. A substance poised so that the application of any extraneous force, or the removal of any of the props which support it will topple it over, is in "unstable" or *dangerous* equilibrium. A substance which can only be disturbed by the application of some extraneous force, and which when that force ceases returns to its original position, is in "stable" or *safe* equilibrium.

As another illustration, all horses are at times controllable or "safe"; all horses may at times run away or become "dangerous." But the horse which runs away only from some specially startling cause, and tends to quiet down again when that cause is removed, is a "safe" horse; the horse which is only manageable under the watchful care of a good driver, and when he does run away becomes more and more excited and uncontrollable, is a "dangerous" horse. The livery-stable keeper who has to turn his horses over to the tender mercies of all sorts of drivers prefers the "safe" horse every time; though for his own use he may choose the "dangerous" one as good enough for him and quite safe in his hands.

The three illuminants used by the three different systems of car lighting which are alone now prominent are: (1) Mineral sperm oil of 300° F. fire test; (2) a fixed gas; and (3) the lightest form of gasoline, of 88° Beaumé, which it is emphatically asserted in all instructions for using the plant must not be any heavier, but which may be and often is lighter, running down often if not frequently [See page 67] to 91° B. gasoline, which boils at 82° F. under 3 lbs. pressure.

Measuring these three substances by the standard we have endeavored to define, and considering them only as substances, apart from the plant used for burning them, it will not be disputed that the first two, heavy oil and a fixed gas, are justly definable as "safe" substances. Long experience has shown that they may be used by millions of ordinary men with no more than the usual and instinctive care which the millions give, with such an approach to impunity as to make accidents the rare exception.

By the same standard, gasoline of all gravities, and especially the light 88° to 91° gasoline, is a "dangerous" substance, one of the most subtle and elusive combustibles and explosives known to man.

It does not follow that it should not be used. It does not follow that its use may not be made safe and justifiable. Steam itself, man's best and (as yet) sole efficient servitor for power, is a substance of like nature, though in much less degree.

But if the use of gasoline be made safe, it can only be the "unstable" kind of safety, from the nature of the substance. It may be perfect while the props and balances which maintain it are perfect, but it is liable to "slop over" into danger if any one of these props fail. There is a presumption against the general use of gasoline as a car illuminant, therefore, which does not exist against the use of either one of the other illuminants. The burden of proof is not upon him who suspects it to be dangerous; it is upon him who asserts it to be safe. He is not doing justice to himself or to the public who does not assume and maintain toward the use of such an illuminant for car lighting a mental attitude of keen, unyielding skepticism until it is proved beyond a shadow of doubt that (1) there are material advantages to be gained by its use, and (2) that the plant in which it is used is so perfect in design and function that it involves no liability of "slopping over" into danger in unexpected ways. For it is to be remembered that the case is not as with steam, where the choice lies between using steam and going without power. If there were two or three other means of developing power, by which as many horse power could be obtained at equal or less cost, the question of whether or not the risks attending the use of steam boilers were expedient or justifiable would assume a very different aspect from what it has now. With steam we have no rational choice; with car lighting we have.

We now proceed to consider what theory and experience indicate in regard to the safety of the several plants as actually constructed and used, beginning with the compressed gas system, the only form of which now before the public is the so-called Pintsch gas plant.

THE COMPARATIVE SAFETY OF THE PINTSCH OIL GAS PLANT.

The manufacture of the gas is essentially similar in its processes to the manufacture of coal gas, which has been carried on for over half a century* in every considerable town of the civilized world, with so few accidents as to make it one of the safest of processes. Occasionally small accidents occur, gasometers are struck by lightning, pipes leak into a parallel conduit filled with air, and an explosive mixture is formed; but the exceptions merely prove the rule.

Experience and analogy seem to indicate that the same is true in substance of the Pintsch gas making plant.† We have been able to obtain record of only two accidents to any of these plants, about 175 of which are now in operation. A somewhat similar plant, known as the Foster plant, but with important differences of construction and arrangement, had two explosions, one at Ludlow, Ky., July 15, 1888, by which over 15 persons were injured, and one at Reading, Pa., March 3, 1890, by which several persons had "narrow escapes." The first accident was caused by an escape of liquid naphtha (which the now defunct Foster company used instead of crude petroleum to make gas from) from a pipe connection with the naphtha reservoir,* which caused the naphtha reservoir to explode; the other† was also an explosion caused by a fire, and apparently of the same nature. The gas tanks did not explode, though the building was completely destroyed, and it was expected that they would. In both of these instances, the only serious accidents to "oil gas" plants of which we have record, inexperience and faults of construction may reasonably be regarded as the cause of the accident, and as peculiar to the now defunct Foster plant. There was also an explosion which blew out a window of the Pintsch gas works at Mott Haven, N. Y., Nov. 15, 1889. It did not destroy the storage tanks, nor do any injury of moment to the plant, the company informs us, and originated from a leak in a retort in the gasworks. A similar but slighter explosion, due to causes explained in a letter from General Superintendent Olhausen, reprinted below, occurred March 16, 1891, at the gasworks of the Central Railroad of New Jersey, in Jersey City. The doors and windows were blown out, and two men were quite badly burned.

---

* The use of artificial gas was one of Mr. WM. MURDOCK's inventions, and was used for lighting the shops of Boulton & Watt, in 1798. Its use became general in London, where the first works were erected in 1816.

† The company claim that the Pintsch gas-making process is safer than that for ordinary coal gas, and advance some plausible reasons therefor, which it has not seemed feasible to investigate with sufficient care to express a positive opinion on them.

---

* See *Cincinnati Inquirer*, July 15, 1888, for details.

† See Philadelphia *Evening Telegraph*, March 3, 1890, for details.

Doubtless other incidents like that at Mott Haven and Jersey City have occurred elsewhere with Pintsch gas, as they do at rare intervals with ordinary coal gas, but they appear to us to be so few and unimportant as to leave the process of manufacture as safe as ordinary gasmaking.

The process of charging may cause accident by moving the car while the hose is coupled on, causing rupture of the hose and escape of gas, which is ignited. The company admits three instances of the kind (i.e., of the rupture) within eight years. There are but two records known to us of consequent accident to person or buildings from this cause. Doubtless there have been other like cases. In one case last fall, at the Grand Central Station in New York, a man was burned and a car set on fire and destroyed, by escape of gas due either to rupture of a hose or carelessness in coupling. The Pennsylvania R. R. has been charging tanks with coal gas in this way, while cars were stopping at stations, since it introduced gas lighting in 1872, 20 years ago. No instance of such rupture by careless neglect to uncouple was recalled by its officers a year ago, but about six months ago one did occur to a night express at Harrisburg, due to the moving of a train by a shifting engine while a car was charging. The escaping jet from the charging pipe was shut off at once, but the escape from the car tank was set on fire by the car-fitters' torch while attempting to extinguish it, and he was burned by the flames.

Not a single instance is on record of a car gas tank (or storage gas tank) exploding, either as an effect of heat or concussion. The possibility of exploding a car tank by concussion was made the subject of tests by Mr. G. M. HUNTER,* with the result that blows of a weight of 400 lbs. falling 15 ft. on a 16-in. recipient heated by fire, failed to cause any explosion even when a puncturing appliance was added. In a number of cases broken car wheel tires have punctured tanks, letting the gas escape without injury. Out of a number of collisions affecting cars supplied with gas tanks, there was a "most disastrous" one on the Seacombe, Hoylake & Deeside line, in England,† the carriages being "considerably knocked about." One train had the lamps lighted, and the other not. "No accident of any sort happened with regard to the lighting." The Pintsch tank is exceedingly well constructed, with welded joints throughout, tinned inside and out, and tested to 300 lbs. pressure. Should a tank ever by any chance give way under its maximum pressure of about 150 lbs., we need not explain to our readers that no explosion could occur, as with a steam boiler under that pressure, there being no "magazine of explosive energy" to cause it to do so, like the heat stored in the water of a boiler. The tank would merely rip open enough to relieve the pressure.

There have been one or more mistaken newspaper reports, however, of "gas tanks exploding while being filled." One such (the only one we know of) resulted from a gas explosion in a car, which occurred at Jersey City, Feb. 12, 1891. In the *Evening Journal* and *World* of the next day, it was stated that the head of the gas tank blew out and was driven through the adjoining car. These reports were reprinted and sent about by circular, of which we received a copy. We immediately addressed a letter of inquiry to General Supt. J. H. OLHAUSEN, and received from him the following reply:

---

* *Eng. News*, April 13, 1889; Trans. Inst. C. E., vol. xcv., p. 224.

† Trans. Inst. C. E, vol. xc., iii.; paper by ARTHUR AYRES, p. 45.

Sir: Answering your letter of 15th inst. I would state that the articles published in the *Evening Journal* and the *World* regarding gas explosion at Jersey City on Feb. 13 are erroneous. There was no explosion of the cylinder or tank. The facts are that an obstruction was noticed in the gas pipes of parlor car "Dahlia" and our men thought they could remove this obstruction by blowing gas through the pipes under heavy pressure. Unfortunately for them, the car was closed tightly (both ventilators and windows) and they never thought about opening these when gas was blown in the car. They went into the car afterward to shut off the different burners, and while doing this the explosion took place. It is presumed that the gas ignited from either a lighted cigar or pipe; it may possibly have caught from the fire in the Baker heater. Under similar circumstances any gas, if good, would have exploded. The explosions caused no damage whatever to the gas attachments of the car; the only damage done was the breaking of car windows and disarrangement of curtains and some woodwork.

The other accident referred to in circular [the explosion at the gas works at Jersey City, March 16, 1891, above noted] is explained as follows: One of the pipes in the gas house stopped up, and in some way the oil seal on the outside became loosened and blew out. Some of the oil caught fire and communicated to a small supply tank. The loss in this case amounted to very little, and we have rearranged the pipes in a way which will render it almost impossible for another accident of this kind to occur. [Arrangement described on page 111.]

By using ordinary care I see no reason why the Pintsch gas is not as safe as any other system of car lighting. If I had not thought it was perfectly safe, we certainly should not have adopted the system on this road.

Yours truly, J. H. OLHAUSEN, General Supt.

Jersey City, N. J., April 16, 1391.

There is at least one instance on record where the puncturing of a tank caused a very serious disaster by ignition of the gas, at Wannsee, Germany, on the Berlin & Potsdam Railway, in 1887. A passenger and freight train collided, perforating the gas tank under a second class carriage. The escaping gas was in some way ignited and several passengers (all those in one compartment, we infer) were burned to death before they could escape. We have learned of no other such accident to a Pintsch tank, but one of somewhat similar nature happened to one of the Pennsylvania coal gas tanks at Thompsontown, Pa., soon after coal gas lighting was adopted, or late in the '60's. The gas cylinder was then in the closet, the pipes became disarranged, the whole contents of the tank were discharged into the car and caught fire from the car stove, and nine passengers lost their lives The fault here of course was placing the tank inside the car. There was also another case some years later on the Pennsylvania R. R., when a car with a gas tank under it turned over on its side in a cut, rupturing the tank or connections, and letting a stream of gas escape which in some way was ignited, burning a passenger and the side of the car somewhat. There was also a case on the Alton last year where a glancing side collision with a locomotive ruptured a pipe, the gas taking fire from the firebox and burning the outside of the car somewhat.

We have also learned, in the process of our inquiries, of a case where an oxygen gas tank of about the size of a Pintsch receiver exploded in England some 22 years ago, with consequences not on record. Such an instance is hardly pertinent, since the presumption is that the construction of the tank was faulty.

An escaping jet of any gas under high pressure is exceedingly difficult to ignite. To light freely a pressure of only an ounce or so is desirable. Recent experiments in Ohio have shown this as to the Pintsch gas. The present writer found it to be true of an escaping jet of natural gas, which it was impossible to ignite with a match held in any position, though under low pressure it was as readily ignited as any gas. Of course the high pressure is by no means an infallible protection against ignition, but it is some protection.

There was a serious accident near Paris, July 29, 1891 (C. de F. de l'Est) where it was reported in the daily press that "A gas tank had exploded and caused fire." This report was unfounded. A copy of the official report on the accident has been furnished us, from which it appears that the gas plant had nothing to do either with the causes or effects of the disaster. A tank engine without tender was derailed, and two cars behind crushed upon it and took fire from the firebox. The gas plant was intact throughout after the disaster, though a leak had been started through which the gas escaped.

One of the most frequent causes of accident from city gas is its escape into a closed chamber, forming an explosive mixture with the confined air. Should gas escape from a Pintsch burner, however, it escapes into a closed chamber, having direct and free communication with the outside air, and the gas being lighter than air, unlike carbureter gas, it tends to rise and escape at once. Hence, if there be escape from the burners, gas cannot remain about the lamps to cause trouble when the globe is lowered to light it. Nor is the gas likely to accumulate within the car to any dangerous extent if the globe be broken and the flames extinguished by some accident. Such an accident either will or will not crush in the upper works of the car. If it does, the gas readily escapes, since it rises in air. If it does not, then the passengers have room and opportunity to escape. The rate of combustion (12½ to 13¾ cu. ft. per hour per car) is so slow that a car would have to be hermetically sealed for some little time to make it dangerous to confined passengers. No instances of trouble from explosive or asphyxiating mixtures are on record to our knowledge, under ordinary conditions, or under any conditions except as detailed above.

This system was introduced in Germany in 1871, and into England in 1876. It has since been in large and increasing use, being now used on about 38,000 cars and (in Germany) on nearly 1,000 locomotives. In view of this record of service with so trifling a record of accident, experience would seem to have established that it is an eminently safe system; approaching as nearly to perfect safety under all conditions as it is reasonable to expect from any system using a flame as the source of light, not to say from any system of any kind. "A priori" reasoning, from the fact that it is difficult to put one's finger on a single feature of the system which one might expect to prove a source of danger, except under some rare combination of unfavorable circumstances, leads to the same conclusion, independently of the records of experience.

A strong feature of the plant is that it is free from the danger of secret degradation of the quality of the illuminant, in order to make larger profit from a cheaper article, which has proved to be one of the most serious dangers with oil lamps. The comparative safety of this latter system of lighting we will now consider.

THE COMPARATIVE SAFETY OF OIL LAMPS.

By far the most frequent cause of accident with oil lamps has been the inferior quality of the oil used. It was not until car lighting by oil had been some time in use, and had given warning of the danger of low proof oil, that such a thing as 300° F. fire test oil was on the market. Even now there is very little of it on the market. Recent official tests in Ohio showed that very little of the oil in use came fully up to this standard, and much of it fell far below it. Oil of 110° to 120° F. fire test was used at first for both house lighting and car lighting, and it is still considered fit for household use, and the accidents from household use of kerosene then resulted and still result chiefly from oils of a still lower proof than 110° F., which are not only cheaper, but pleasanter to use, except for their danger.*

After the high proof oil was introduced for car lighting it was a long time before lamps well adapted to burning it were introduced, and before roads appreciated the necessity of testing their oils before acceptance. The roads which test oils properly and faithfully are still the exception, and as the lighter and more dangerous oil is cheaper as well as more light giving, not a little of it still creeps into use. Only last year there was a serious accident in Ohio (but without loss of life) caused by the use of such oil. A whole train of cars was burned up, with heavy loss. All cases in which lamps are truthfully stated to have "exploded" may be set down with certainty as due to the use of low proof oils. Beginning with a frightful accident on the Great Western of Canada, in which eight persons lost their lives under peculiar circumstances detailed in our issue of April 26, 1890, we might give quite a list of such accidents due to the use of inferior oil, possibly a dozen or more, as on the Savannah, Florida & Western, Jan. 28, 1888, where five cars were burned as an effect of the explosion of a lamp. It is a suspicious fact, however, that many of these alleged explosions of lamps have occurred in winter, when stoves are also going. Thus in January, 1890, a mail car on the Iron Mountain road, standing locked up on a side track, took fire and burned up, "it is supposed from an oil lamp exploding." The supposition may be true, but if true it is less discreditable to the men responsible for the car than if the stove had set it on fire.

---

* The regulations for testing oils on various roads were given in our issue of Sept. 26, 1891.

The same suspicions attach to some of the instances where the quality of the oil is not open to suspicion, as in the much discussed accident on the Cincinnati, Hamilton & Dayton, Jan. 17, 1890, in which all the passengers in two cars (fortunately only five) were killed or burned alive, and most of the train burned up. Mr. C. H. CORY, Supt. of Motive Power, says in regard to this accident:

> As regards the fire in the accommodation train, it was not caused by either the engine or the stoves [plain cast iron ones.—Ed.], but was caused by the oil lamps in one of the cars being knocked down by the cars telescoping together and causing the fire, the stoves in both ends of the car that was telescoped having remained bolted to their places in upright position, and no fire whatever scattered from them.

If this testimony be accepted as conclusive, this is the most notable accident caused by oil lamps which we have been able to discover since the record opened with the Canadian accident above noted. Few of the fires set by lamps of which we have record have done more than destroy the car. It is fortunate fact that the usual effect of a general smash-up is to extinguish the lamps. We have heard of a few such instances, as one in September, 1874, where a lamp in a sleeper on the Wabash R. R. fell down and set fire to the car, which was switched off and entirely consumed. In another like case on the same road, however, in October, 1876, a lamp was shaken loose as an effect of a derailment and set a seat on fire, but it was promptly extinguished by a brakeman. A good many accidents of this nature may easily have occurred, of which no record exists. It is to be remembered always that it is specially difficult to obtain information about minor accidents which do not get into the newspapers, especially if they occurred some time ago; but we also made special efforts.

Beginning with April 16, 1890, a notice was published for five weeks on the editorial page of Engineering News, asking anyone who might know of instances where accidents from fire or otherwise had been caused by the use of oil lamps for car lighting, to inform us as to the date, place and circumstances of the disaster. This notice, which was reinforced by a number of personal letters to and inquiries of persons who might be supposed to be well informed, elicited just seven responses, *i. e.*, seven alleged instances, most of which are listed above. All of these, and all of some two dozen other alleged lamp accidents, of which we have found record in print, belonged to one or the other of the following classes:

1. Fires set by lamps "exploding" or otherwise giving evidence that low proof oils were being used.
2. Fires set by lamps shaking loose from their fastenings, because of bad mechanical details which (for the most part) are now obsolete. The best car lamps on the market, so far as we are advised, cannot possibly be shaken loose after they are once in

place by any force short of one which will tear the lamp from the socket.

3. Fires alleged to have been started by car lamps, but occurring in winter and in cars heated by stoves which had fires in them at the time, so that the correctness of the diagnosis is open to suspicion ; and

4. Accidents of so slight a nature that the attendant circumstances are not clearly recorded.

The list of fires set by stoves as an effect of train accidents is a long and still increasing one. Our list of fires similarly set by lamps, and to which lamps only could have contributed (i. e., of fires occurring as an after effect of collisions or derailments when lamps were lighted and there were no stoves in use nor other known cause to start fire) is an absolute blank. We have done our best to get track of such incidents. We have not discovered a single one. If any reader knows of one or can refer us to anyone else who does we beg that he will do so. If there be any instances they must at least be very few and of slight importance. In fact, the serious accidents of any kind, which are in any manner charged to lamps and have been attended by the loss of more than two or three lives, cannot well number a dozen, all told. Out of all the railway accidents which occur and are of sufficient importance to get into the newspapers, the average of the past 20 years shows that about 8 in 1,000 only are due to "cars burned while running." We have examined the records of such accidents with some care and the vast majority of them occur in winter, and are traceable to car stoves or to sparks from the engine, or originate in hot boxes or combustible freight. The oil lamp fires are an insignificant fraction, though more likely to be reported in the newspapers than the fires from the other causes.

The records of the Railway Mail Service show very accurately all casualties which occur to persons or property in nearly 3,000 passenger train cars, which on an average are rather more exposed than other passenger cars. The record for 1891 [see Engineering News, Feb. 13, 1892] stands as follows:

Entire cars in use	500	
Entire cars in reserve	110	
		610
Cars with postal apartments, in use	1,781	
Cars with postal apartments, in reserve	500	
		2.281
Total number of cars		2,891
Total number of railway clerks		5,514
Total casualties to cars (collisions, 112; derailments, 122; other, 85)		310
Wrecks followed by fire (1 set by stoves, 2 by lamps, 9 unstated)		12
Cars took fire without wreck (2 set by stove, 1 by steam pipes, none by lamps)		5
Injuries to mail from oil spilled as one of the consequences of a train accident (usually as an effect of overturning or severe shock)		45
Postal clerks killed, 13; seriously injured, 68; slightly injured, 84 (none in consequence of fires set by oil)		165

Kerosene of 110° fire proof, or thereabouts, is now burned in large quantities in almost every household in the United States, city or country. At a guess there may be 40,000,000 kerosene oil lamps in use in the United States. There are a good many accidents therefrom, but, after all, how few proportionately. Most of those which do occur are traceable to the use of very low proof oil, and the few which remain are for the most part traceable to the formation of dangerous naphtha vapors which cannot originate in 300° fire test oil, as there are no naphtha constituents left in that oil, though there is a good deal left in household kerosene.

For example, the frightful accident to Secretary TRACY's family in the winter of 1890 was due, it was thought with some reason, to the explosion of an oil lamp which had been carelessly turned down and then left burning through the night. Under these circumstances the best household kerosene may generate an explosive gas, but not 300° oil. The very fact that, though such oil is demanded for cars, 110° oil is considered quite good enough for household use, is alone proof that too few accidents result from the household use of 110° oil to warrant any higher standard, for the difference in wholesale price between 110° and 300° oil is so little that the retail price to families (about 10 cts. per gallon in New York) would remain about the same.

Mr. EDWARD ATKINSON, the well known economist and expert in fire risks, President of the Boston Manufacturers' Mutual Insurance Co., which insures over $500,000,000 at very low cost under unusual conditions of critical expert inspection and control, as most of our readers know, informs us that in the 150 or so factories which they insure, no fire loss exceeding $1,000 is on record charged to kerosene, and that the first fire loss chargeable to electric lighting lately occurred and amounted to $500. They find the risk of fire from oil lamps to be quite a minor one. Yet we may note here better than elsewhere that in all these properties where kerosene is used so successfully for lighting, the use of gasoline or naphtha in any form for lighting purposes (except in the open air at a distance from buildings) is absolutely prohibited.*

In both car lighting and house lighting there are undoubtedly a great number of small fires or burns which never become of public record, yet which, in the aggregate, cause far more loss and suffering than those which do. We have been told by well informed persons that the losses of the sleeping car companies from carpets injured by oil alone amount to over $200,000 yearly. We have not been able to obtain any official records to that effect. Official records are hard to obtain on this subject, but we believe it to be true.

It is also certain that oil reservoirs in the vicinity of fires started from other causes will help to aggravate and spread them. It can only do so as a fuel, however (*i. e.*, by locally intensifying the fire) not as an explosive or specially quick combustible; and it has been plausibly claimed that when the victim of an accident is pinned fast, close to an incipient fire, the fiercer the fire in his vicinity the sooner his sufferings are over, as a rule. If he is to have fire brought rapidly to him, which otherwise might not reach him at all, it is a different matter.

---

* The Boston Manufacturers' Mutual Fire Insurance Co., had last year about $93,000,000 of insurance in force, on which the total losses were a fraction less than $300,000, or somewhat less than a third of one per cent. These losses resulted from 257 separate fires, of which 11 only were from kerosene lamps, 11 from gas jets, and 4 from electric lighting. The proportion of fires due to the means of lighting will be seen to be extremely small, only about a tenth of the total fires being caused by all three of these modes of lighting together. From this it would appear that the normal proportion of losses chargeable to all methods of lighting together is, with this $93,000,000 of property, in the neighborhood of $30.000 per year. We do not know what proportion of the mills are lighted with oil, and what with gas.

The flames of oil lamps are quite sensitive to shock. As a rule which may have rare exceptions, any blow severe enough to break the metal parts of the lamp will also extinguish the flame. The oil can hardly be made to take fire loose on the floor, but ignites more easily if spilt on a carpet.

Kerosene oil has for many years, since 1870 at least, been the standard car illuminant in this country. At the present time, although other methods of lighting are crowding oil out, all but about 4,000 passengers cars at most in a total of some 40,000 in the United States and Canada are still lighted with it.*

---

* A committee of the American Railway Association issued in 1891 a circular letter of inquiry as to lighting passenger cars, the responses to which were as follows:

Do you consider it an essential requisite in lighting passenger cars:

1. That sufficient light shall be afforded to enable passengers to read without difficulty in any seat of the car? [Yes, 63: no, 26; unclassified, 12.]

2. That the light shall be obtained at a reasonable cost? [Yes, 90; no, 2; unclassified, 4.]

3. That each car shall have an independent source of illumination; hat is, that it shall not be necessary to take the car to any given station to receive its supply from a special plant? [Yes, 68; no, 12 (but representing 31% of the cars responding); unclassified, 16.]

4. That the light shall be easily managed, cleansed and regulated by the trainmen, and that it shall not be peculiarly dangerous in ordinary use or in unskilled hands? [Yes, 90; unclassified, 3.]

How many passenger cars have you in service lighted by mineral oil? [93 roads report 15,861 cars.]

How many passenger cars have you in service lighted

When we contrast the vast number in service for 20 years past with the extremely limited list of recorded accidents which are in any way charged upon the lamps, and when we consider further that nearly all these accidents are traceable to the use of improper oil or lamp fixtures, and that not a single accident of any moment is on record which has been clearly traced to an origin in proper lamps filled with proper oil, the reasonable safety of such lamps and oil seems to be established, by the records of experience alone. *A priori* reasoning, based upon the known properties of the liquid and construction of the lamps would lead to the same conclusion, because no reasonably supposable conditions seem to point to a probable source of accident, as will become evident by running over the various methods by which oil may give trouble. The most that can be said against oil, in our judgment, is that in car lighting as in house lighting, while oil is a cheap and generally safe illuminant, it is also a troublesome one, and a frequent source of little annoyances, accidents and damages, from which most households are glad to escape by paying considerably more for gas, when they have the choice open to them. Gas is also generally

---

otherwise than by mineral oil? [40 roads report 3,068 cars.]

If you have tried any system other than oil has it produced satisfactory results? [Yes, 31; no, 7; unclassified, 6.]

Is there any reason which can be adduced, as the result of your experience, to apprehend greater danger from the use of well constructed oil lamps, using mineral oil of 300° fire test, than from other methods of lighting now in use by you? Yes, 6; no, 57; unclassified, 5.]

held to be the safer, especially where oil has to be used in large quantities, as in lighting halls and hotels, and this consideration doubtless has its influence; but that it has no great influence is indicated by the fact that almost every city household also uses oil lamps, for æsthetic reasons only.

Note: The following miscellaneous extracts from our correspondence in regard to the safety of oil lighting will be read with interest:

Mr. **Godfrey W. Rhodes**, Supt. M. P., Chicago, Burlington & Quincy R. R., writes us:

A couple of years ago one of our oil lamps fell on the floor of a car in some unaccountable way. The car took fire and was completely burned before it could be put out. Persons were in the car at the time, but of course got out, and the fire was confined to the one car. The lamp was supposed to have 300° oil in it [The C., B. & Q. is one of the roads which carefully tests its oil.-Ed.] and was of first class make. It was located in the wash room at the heater end of the car. The end of this room had been partitioned off without providing for any ventilation through the clear story. The result was that the top of the car got to be a little furnace, and our conclusion was that it heated the oil to such an extent that it finally took fire. Since then we have always provided for top ventilation through in partitions where lamps are located, and I think the danger from this kind of accident is entirely removed.

Mr. **W. H. Thomas**, Supt. M. P, East Tennessee, Virginia & Georgia Ry. system writes:

Referring to yours of Jan. 30, 1892, in regard to Pullman car burned on this road Jan. 26, at Plainville, Ga., the oil issued to coaches and sleepers was tested and found to be of first quality. My theory of the cause of the fire was that the porter, after lighting the lamp in the drawing room, left it turned up too high and went out, closing the door after him. The flame from the lamp set fire to the soot and head lining, burning the lamp from its fastening and allowing it to fall to the floor, setting fire to the state room furniture and fixtures. The heat becoming very intense, caused the glass in the door to break, when the flames rushed through the main body of car and destroyed it. The smoke from the lamp escaped through the ventilators in the upper deck of car, and the stateroom, being tightly closed with curtains drawn down, prevented the porter from noticing the condition of the lamp.

Mr. J. H. McConnell, Supt. M. P. of the Union Pacific System, writes us:

We have no record on this road of any accidents resulting from the use of mineral sperm oil, except the disadvantage of the lamps leaking at times and dripping on the carpet in the car.

General Manager Ainslie, of the Wisconsin Central system, writes us:

I have never known of an accident which could be traced to the use of oil of 300° proof.

Mr. Jas. E. White, Gen. Supt. Railway Mail Service, Post Office Department, writes us:

Replying to your inquiry as to whether reports are made to this office of instances where oil is spilled on mails or on the car, I beg to say that we have now in use four different kinds of lights, namely, the Pintsch, the Frost, electric and oil, the oil being used very largely now in what is known as the Acme lamp. manufactured by Adams & Westlake, Chicago, Ill This lamp we find not only gives an excellent light in the car, but is so arranged that the liability of oil overflowing is almost entirely overcome, and I doubt very much whether any considerable quantity of oil is spilled on the car floor or on the mail except when accidents occur.

It is possible and probable that in filling lamps a small quantity of oil is occasionally spilled upon the floor, but my experience with the Acme lamp and with the lamp manufactured at Cincinnati called the Post lamp, is that very little, if any, oil is spilled either on the mails or on floor of the cars, and for this reason we have never considered it necessary to require report to be made of the fact to the Division Superintendents and by them to this office.

Correction.—The Safety Car Heating & Lighting Co. send us the following correction of a statement in the article published last week, discussing the comparative safety of their (Pintsch) system of car lighting:

We wish to call your attention to a very serious error in Chapter XV., "Comparative Merits of Various Systems of Car Lighting" in your issue of March 26, (See page 247, of this book.) The following statement is there made: "In one case last fall, at the Grand Central Station in New York, a man was burned and a car set on fire and destroyed by escape of gas, due either to rupture of a hose or carelessness in coupling."

The facts are the escape of gas was due to a leaky hose, and that the gas was ignited by proximity of a torch. One hand of the car filler was blistered and on one side of the car two outside panels of the wood work were scorched. The entire damage to the car was less than $27. Your statement that the car was "destroyed" is entirely wrong, and is very damaging to our system of lighting. Knowing that your intentions are to be perfectly fair in your articles on car lighting, we must ask you to make a correction of the above named statement.

We cannot now explain how this error arose, but as advance proofs of this, as of all the other articles of this series, were sent out for correction to all supposed to be concerned or well informed, we feel that we did all we could to insure correctness.

THE COMPARATIVE SAFETY OF GASOLINE CARBURETERS.

Compared with the range of experience with oil lamps or compressed gas, that with gasoline carbureters is as yet limited, if reduced to a common standard of car-years. Several thousand car years of experience have already been had with this plant, however, and the record of accidents of any moment from its use is as yet short, and does not include a single death or serious injury to persons to our knowledge.

A wreck at Thaxton's, Va., on the Norfolk & Western R. R., July 2, 1889, clearly demonstrated that fire would not cause the carbureters to explode if the safety valve remained open. A fire was started from the locomotive nearly an hour after a serious derailment. Part of the wrecked train was burned up, including a car lighted with five carbureters.

When the fire reached them they burned like so many torches, or as in the fire tests described on p. 44 *et seq.*, and in no way added to the seriousness of the catastrophe. The carbureters were so little injured that it was not unreasonably claimed that they could have been refitted and applied to a new car.*

The most serious accident known to us which was really chargeable to imperfections of the carbureter light was the burning of a car in service on the Central R. R. of Georgia, May 4, 1891. We have made careful inquiries in all directions as to the real facts of this disaster, which seems to us to have arisen from a heretofore unsuspected form of danger, below explained, and the following appear to be the facts, as nearly as it is now possible to ascertain them:

The Central R. R. of Georgia had caused three new cars, which the Ohio Falls Car Co., of Jeffersonville, Ind., were building for it, to be fitted with the Frost light (three lights to each car). This was applied under the direction of the manufacturers, who also sent a man to Georgia to instruct an employee in the care of the lamps. The latter is admitted to have discharged his duty properly, or at least, no charge of carelessness was made against him, and he was retained in the company's service. The cars had been running between Savannah and Atlanta about one month when the accident occurred. The most authoritative record of the facts which we have is as follows

---

*Mr. R. B. CLAXTON, foreman of the jury which investigated this disaster, gave us, on request, the following summary of the jury's view of the facts, under date of Liberty, Va., Sept. 3, 1889:

"From the evidence adduced it was shown that the train at time of accident was running at a very slow rate of speed, and that the engine had passed nearly over the fill when it gave way. At time of the fire the pilot of the engine was up near the track, on the east side of the washout, the engine resting against the bank. The cars following fell into the washout, some of them being below the engine, when the coals from the firebox fell on the timbers of the cars and caused the fire. It was ¾-hour to 1 hour after the accident before the fire was discovered. From the best of my recollection the washout was about 28 ft. deep and 80 ft. wide.

The car was charged [at Savannah] on May 2 and went to Atlanta that night, returning the following night. On both trips the lamp after burning awhile began to flame up and was extinguished. On the night of 2d, it burned three or four hours. On the next trip from Savannah [May 4, the night of the accident], without additional charging, t burned for an hour or so in shed, but after getting a few miles on road, began to flare up and was put out. After being put out the globe began to fill with gasoline, and when the porter went back to fix it he reported the globe to be quite full and very hot. He put his lamp on the floor and proceeded to empty the globe. The gasoline fell on the lamp and ignited, and the car was at once on fire beyond control. These were the facts as brought out on investigation. The lamp was evidently over harged, and had an expert been on the train on the two previous trips, he would have evidently detected the cause and remedied the trouble. What has never been explained is: Why did the globe fill with gasoline after the flame had been extinguished? and why did this not happen on the first night? I would have doubted the fact of its so filling after being put out, had not the testimony been so direct on that point. Judging from condition of carbureters on the remaining cars, there could not have been a very great excess of liquid in carbureter, and as gas is drawn from top of the carbureter, the liquid must have boiled up and primed over, or a leak must have started in the bottom. As the car was completely destroyed, no evidence was left as to any structural defects in that particular lamp and carbureter.

Another equally authoritative account, and in some respects more detailed, is that when the lamp was seen to be behaving badly, a few miles out of Savannah, and a smell of gas attracted attention, the passengers called the conductor, and he closed the needle valve and went forward through four cars to find the porter. The porter found some accumulation of gasoline in the globe, though the needle was closed, and he then went forward again to get some waste, carrying his lantern with him. On returning he placed his lantern on the floor at some distance from the imperfect lamp (claiming that he had had prior experience with the lamp, and that he knew and appreciated the treacherous nature of gasoline) and opened the globe to wipe it out, having no match or fire about him. As he did so he was enveloped in flames, and was somewhat badly burned, but stopped to pull the bell rope. The passengers were watching him, and all escaped without injury, and the conductor, who also had warning, quickly took the necessary steps to cut the burning car free from the train, which stood on the track till the car had burned out (there being three sleepers behind the car). The train then coupled up and proceeded, the trucks of the burned car being thrown off the track.*

---

* The newspaper accounts of this disaster were given in Engineering News, May 6, 1891. The following is

These facts seem to us to indicate that the primary cause of the disaster was that one of the three lamps had not been burned for the two preceding nights, causing a distillation of gasoline from the lighted to the unlighted carbureters, with or without some aid from a leak in the upper part of the carbureter. There can hardly have been a leak in the lower part, or the accident (or trouble of some kind) would have come sooner.

On Aug. 30, 1891, an incident of some significance, which fortunately did not result in accident, happened to the private car of Senator CALVIN S. BRICE, President, Lake Erie & Western R. R., which was lit by five Frost lamps. At St. Paul, Aug. 28, Porter YOUNG had filled the carbureters, using about 10

---

from the official report of the Superintendent of Motive Power to the General Manager: "Regarding burning of passenger coach of this road, lighted by Frost system, on May 4, 1891, conductor and porter said rear lamp in coach did not work well before leaving Savannah. When about four miles out it went out, and remained out for some time, when odor of escaping gasoline attracted attention of some of the passengers; when one of them went forward and notified the conductor, who closed needle valve on lamp, and went to baggage car and instructed porter to light it. When porter arrived he found quite an accumulation of gasoline in globe, and tried the needle valve and found it closed. He returned to baggage car for some waste cotton to absorb the gasoline, and on his return found the globe half full of this liquid. Before reaching the lamp (knowing the dangerous nature of gasoline, having had experience with it on other roads), he took the precaution to set his lantern down on the floor in the center of the car. The moment he opened the globe, the confined vapor escaped and ignited, and he immediately was enveloped in a sheet of flame. The coach was standard 50 ft., and had three of these inverted lamps." In the minor details wherein this account differs from the above it is probably less accurate, being of earlier date.

gallons of gasoline. He had to use a "gravity lighter than 86°"; he thinks 4° or 5° lighter. [The standard is 88°.] The next two days were bright and very warm, but the interior of the car was probably cool, the porter thinks from 65° to 70°. The porter could not say whether he filled the carbureters too full or not. At Chicago, on the evening of the 30th (Sunday), the car was standing in the yard, and the porter was alone. He had not lighted the bedroom lamp, but thought he would light it, as all the other cars around were lighted. On opening the valve of the lamp, instead of gas, liquid gasoline isused at the rate of two drops per second, the porter thought, and caught fire as it came out, falling to the floor and not into the glass globe, as that was lowered. About 1½ tablespoonfuls, he thought, ran out. He immediately turned off the cock and blew out his match as soon as he saw gasoline was issuing and did not again attempt to light the lamp.

About two years since a new day coach which was being built at Pullman, Ill., for the Union Pacific Ry., equipped with carbureters was reported to be destroyed by fire caused by gasoline, but just how we have not been able to learn, if, indeed, the precise cause is known. In regard to this incident, and their experience generally with carbureters, Mr. J. H. McConnell, Supt. M. P. and Mach., U. P. Ry., writes us under date of Jan. 19, 1892:

> We have some 40 cars equipped with carbureters. As to the matter you asked about—car being destroyed by fire at the Pullman works from use of carbureters—am unable to give you any information, as we have no record of it here. Inexperienced persons handling the

carbureters, by turning the valve open too wide, have caused the head lining of the car to be smoked on several occasions.

We experience more difficulty from carbureters in cold weather than at any other time, as they do not burn well, from the fact that the gasoline becomes chilled and does not vaporize readily. In extremely cold weather we find it difficult to make the lights burn. We have tried to overcome this by numerous experiments, but so far have not succeeded in making a good light when the weather is below zero. In warm weather the light has given us good satisfaction.

On Feb. 20, 1891, a parlor car on the Chicago & West Michigan Railway was slightly damaged by a fire originating, it is supposed, in overcharging of one of the carbureters. The facts of this occurrence, we are advised by the superintendent of motive power, were as follows:

We had four cars equipped with the dry carbureter system, and on Feb. 20, last, our parlor car No. 6 was slightly damaged by fire, originating from one of the lamps which had been overcharged with gasoline. There were seven panels of headlining ruined, the varnish of the clear story blistered and a few deck lights broken. The lamp and carbureter were not injured, except that the globe was broken. The responsibility for this accident is wholly charged to one of our employees, who neglected to follow his instructions in charging the carbureter. I might say, in connection with the subject, that this slight fire, while not directly chargeable to the device, resulted in considerable prejudice on the part of those who do not understand the principle of the light, and we have removed the same from the car and replaced with Acme burners (oil lamps). This, I think you will appreciate, is on my company's part in the direction of overcoming a public sentiment that frequently necessitates a change of some kind to allay prejudices, which, at some future period, might be somewhat to our disadvantage.

Another prominent superintendent of motive power, who has had a good deal of experience with carbureters, writes us:

> "We have not had any trouble with carbureters, excepting that when we first commenced using them on one or two occasions the carbureters were overcharged. This allowed under some conditions liquid gasoline to go through the burner in place of gas. It would result in an occasional big blaze of light (flame) which was startling to occupants of the cars, to say the least of it. Now that we know of this difficulty there is no more trouble from it."

On the other hand, General Manager AINSLIE, of the Wisconsin Central lines, writes us:

> "We have two trains equipped with the carbureter lighting system, which have been in service for nearly two years. We have had no accidents, and our experience with the latter system indicates that it is a safe light to use."

The Pennsylvania Railroad, which has had by far the longest and widest experience with this lamp, has had no accidents from its use, and no misbehaviors of the lamp threatening accident, so far as we know or can learn by careful inquiry, except the following: In one case the globe of a lamp in service became filled with flame, and the attendants knocked the lamp down with an axe. In another case the globe became filled with flame but the lamp was extinguished without resort to such extreme measures. Also, about a year ago, a car at the Jersey City yard was about to be charged, and six 2-gallon cans were standing by for charging it, when fire was started in some way never accurately determined, and communicated at once to the car, which, however, was not entirely destroyed. After the fire the cocks of the six charging cans were all found to be open, and it is inferred that vapor was escaping from them and was by some means ignited.

Several other alleged instances of trouble from the plant on various roads have been reported to us and inquired into, but they have always proved to be without known foundation. Having made every effort to collect all reports of casualties from this as from other systems of car lighting, no authenticated records except those above noted have reached us.

On the other hand, during the period covered by our investigations, numerous reports illustrating the damages of gasoline in an unconfined fluid form have reached us. We will quote only two, one a railway disaster and one a house disaster.

On April 14, 1891, a broken journal on a Great Northern Ry. train near Rothsay, Minn., caught in the ties of a trestle, and threw a whole train into the ravine, except the engine and three cars. Among the wrecked cars was one car of gasoline, which was ruptured, and the vapor of the gasoline reaching up to the engine firebox (as was supposed) and carrying fire from it back to the wreck, instantly set the whole train and trestle on fire, causing a loss (by newspaper reports) of some $100,000.

On March 7, 1891, a St. Louis lady, who was housecleaning, tired of dipping out gasoline slowly for cleaning some tapestry curtains hanging between two rooms, poured a quantity of gasoline (one account says two gallons) into a tub or basin, and proceeded in her work. She spilt a little on her dress. She had hardly begun work when fire was carried to her dress from a stove in one of the rooms. She rushed screaming from the room, but was prostrated by an explosion at the front door, where her burning garments "burned a great scar on the hall flooring and upon the east base-board." The house was considerably shattered by the explosion, and finally burned down. The lady died in a few hours. A servant girl had just left the room, and escaped to narrate the cause of the disaster.

Great numbers of such disasters from liquid gasoline might easily be given. Its vapor has two objectionable qualities which tend to make it more dangerous than other inflammable gases. (1) It adheres readily to clothing, soaking into it like water, and (2) it is so much heavier than air that it flows through it and collects in pools almost as water would. Yet, on the other hand, it is used largely and continuously in many households, without accident. A high official of a great Western railway, universally known and respected, informs us that he has used a gasoline stove in his household for many years with entire immunity from accident; and that in view of the great additional safeguards thrown around the use of gasoline by the Frost carbureter plant, he feels quite warranted in using the latter for car lighting, which he does quite extensively. *

---

* That this is not a universal experience, however, is shown by a newspaper item which chances to strike our eye while revising proofs of this article, as follows: "Manning, Ia., March 21.—The explosion of a gasoline stove used to heat water in the baptismal font in a church

Passing from the record of experience, which, it must be admitted, is not yet sufficiently extensive to be decisive either way, we proceed to summarize the technical facts bearing on the question of probable permanent safety.

1. Gasoline is not a simple fluid like water, in which every particle has the same boiling point, but a mechanical mixture of the "paraffine series" liquids (see p. 4), in which the separate particles have different boiling points. When heat is quickly applied the whole mass assumes a mean boiling point (for 88° B. gasoline about 110° F.); when heat is slowly applied the lighter parts evaporate first.

2. Much commercial gasoline of so-called 88° Beaumé gravity is really of lighter gravity. In Baltimore the commercial 88° gasoline is mostly 91°, boiling at 83° F. under 3 lbs. pressure.

3. Gasoline is one of the hottest of combustibles, owing to its high proportion of hydrogen and lack of any non-combustible elements. It generates in combustion about 27,400 heat-units per pound, turpentine, for example, only generating 20,110 h. u. and coal or pure carbon some 14,500 h. u.*

---

here yesterday wrecked the font and set fire to the clothing of the minister, the Rev. Mr. Boles, burning him fatally."

*The following gives the chemical composition and heat generating capacity of a few of the hotter combustibles:

Substance.	Chem. comp	P. c. hyd.	H.u.per lb.	Evap. lbs.
Gasoline ..	$C_7 H_{16}$ to $C_8 H_{18}$	about 27 3	27,520 27.300	24.75
Turpentine.	$C_{20} H_{16}$	11.8	20,110	18.2
Alcohol.	$C_4 H_6 O_2$	14.3	12,929	11 7
Olefiant gas.	$C_4 H_4$	14.3	21,330	19.3
Pa. crude petr'm....	$C_{85} H_{15}$ (etc.)	13.	20,240	18.3
Carbon.	C	0 0	14,544	18.3

The per cent. of hydrogen for alcohol is for the com-

This amount of heat is sufficient to convert 24¾ lbs. water at 72° into steam at 212°, about twice the heating capacity of ordinary coals.

3. The latent heat absorbed in vaporization by gasoline from the liquid at 72° F. to steam at atmospheric pressure is low, about 1-5 (19%) only that of water.† Therefore the heat produced by the combustion of 1 lb. of gasoline will convert into steam about 5 times as much gasoline as water, or exactly 24.75 ÷ 0.19 = 130.3 lbs. of gasoline. Something less than 1% of the heat of combustion, therefore (exactly 0.77%), if applied to vaporization, will maintain a continuous supply of gasoline vapor, without any assistance from an air supply. In order that the

---

bustible hydrogen only, excluding that which combines with the oxygen. The evaporation is in pounds of water at 72° into steam at 212°, absorbing 1,106 h. u. per lb. of water.

† According to the best available authorities gasoline absorbs only 150° per lb. in the actual process of vaporization or 190° from liquid at 72° to steam at (say) 112°, or 17½% of that of water, which absorbs 1,106°. As there is some doubt upon this point, however, we take the total heat to be 210° instead of 190°. We cannot learn that any tests have ever been made on gasoline. Prof. J. E. DENTON, of the Stevens Institute of Technology, writes us as to existing records: "The only experiments with anything resembling naphtha, are to be found in the third volume of REGNAULT'S (Experiments) or 'Compte Rendus' about 1843. I understand, however, that what he calls naphtha is not identical with what is now used under that name. The only experiments on this substance are those reported Art. 135, WOOD'S 2d ed. 'Thermodynamics,' where the latent heat is given as 237 thermal units per lb. for a pressure of 60 lbs. above the atmosphere. The figure is an approximate one, as the degree of superheating present was not accurately determined, but it is probably not largely in error." This figure would give a considerably lower heat of vaporization than that estimated above (210°), which is based on data given in D. K. CLARK'S "Manual for Mechanical Engineers."

vaporization may be sufficiently rapid to make a good light, however (see page 7), a temperature of 80° to 90° or more is required and obtained.

4. The heat absorbed by vaporization at any given rate is sensibly the same, whether it takes place above or below the boiling point of gasoline. Also,

5. The total heat absorbed by the process of gas making, including that needed to warm up the air supply, is sensibly the same at any given rate of vaporization; whether the amount of air supplied be much or little, and whether the vaporization takes place above or below the boiling point. With about ⅛ air and ⅞ gasoline, as in our burning tests (see page 18 *et seq.*), about 0.79% (i. e., 0.79 of 1%) of the total heat of combustion is absorbed in gas making; with ½ air and ½ gasoline, 0.81%; with ⅞ air and ⅛ gasoline, 0.83%. All the rest of the heat, say 99.17%, is either carried off in the gases from the chimney or dissipated by radiation from the carbureter or goes to raise the temperature of the carbureter.

6. Whether or not vaporization takes place below the boiling point depends, therefore, on (1) how much of the heat of combustion is communicated to the carbureter; and (2) on how much is radiated therefrom. If more is supplied than is radiated, the temperature will in time rise above the boiling point of say 110°.

7. The mass of the carbureter is very considerable in proportion to the heat supplied to it; but, on the other hand, its mean specific heat is low (about 0.17; water being 1.0). Its total weight, including the

casing and attachments, being 160 lbs.;* 27.2 h. u. only (160 × 0.17) are required to raise its temperature 1° F. To raise its temperature from 83° F. to 113° F., (the boiling point of gasoline under about 3 lbs. pressure), or say 30°, requires 816 h. u.

8. The total generation of heat under the conditions of our burning tests† was 6,938 h. u. per hour, of which 0.79%, or 55.78 h. u., is absorbed in generating the gas. If, in addition to this heat of vaporization, we assume various percentages of the total heat from 1% to 30%, to be communicated to the carbureter *in excess of that carried off by radiation*, we find that the carbureter will be heated up from 83° to 113° F. (i. e., absorb and retain 816 h. u.) in the following time:

The percentage of total heat communicated, in excess of 0.8% for vaporization and of the loss by radiation, being

1% 2% 3% 4% 5% 10% 20% 30%

and the heat units per hour represented by these percentages being

69 139 208 278 347 694 1,388 2,081

816 h. u. will be communicated to the carbureter in

11.82 hours. 5.91 hours. 3.94 hours. 2.96 hours. 2.36 hours. 1.18 hours. 0.59 hours. 0.39 hours.

Two actual tests of lamps burning in still air of 75-77° in a large room (see pages 80, 81) showed that 3¾ to 4 hours were required to raise the temperature of the carbureter 40°, indicating that under those conditions 2½ to 3% of the heat generated in excess of the loss by radiation and vaporization was communicated to the carbureter. With the surrounding air in rapid motion the radiation would be many fold more rapid; with still air at 38° F. radiation would be about twice as rapid With the exterior shell of the carbureter heated to 112° radiation would cease. Between these extremes there may be all conditions of radiation.

---

* We refer always to the original circular carbureter. The newer square form is larger and heavier.

† See page 18.

The above computations apply to lamps burning gasoline at the rapid rate of 4.05 oz. per lamp per hour. In Pennsylvania R. R. practice it has been found that about 3.3 oz. per lamp per hour=(1 qt. per hour for six lamps) is burned. At this rate, the above computed times for heating up the carbureter 30° should be increased about 22½%; in addition to which it is to be remembered that the Pennsylvania plant does not direct nearly as much heat into the air passages surrounding the carbureter as do the forms of plant tested. At half this rate of combustion, which we assumed in our article on comparative cost to be a fair vaporizing rate for ordinary practice, about twice as much time would be required as is above computed to heat up the carbureters 30°, under otherwise similar conditions.

These facts point to the conclusion that in wintry air in rapid motion it might be all but impossible to raise the temperature of the carbureter 30° F. above the temperature of the interior of the car in any form of the plant; that, in still summer air, or in strong sunshine, even with rapid motion and with no lamps burning, it might be very easy to do so; and that between the two there may be all conditions, according to whether the car is moving or gallons of gasoline. He had to use a "gravity lighter than 86°"; he thinks 4° or 5° lighter. [The standard is 88°.] The next two days were bright and very warm, but the interior of the car was probably cool, the porter thinks from 65° to 70°. The porter could not say whether he filled the carbureters too full or not. At Chicago, on the evening of the 30th (Sunday), the car was standing in the yard, and the porter was alone. He had not lighted the bedroom lamp, but thought he would light it, as all the other cars around were lighted. On opening the valve of the lamp, instead of gas, liquid gasoline isused at the rate of two drops per second, the porter thought, and caught fire as it came out, falling to the floor and not into the glass globe, as that was lowered. About 1⅛ tablespoonfuls, he thought, ran out. He immediately turned off the cock and blew out his match as soon as he saw gasoline was issuing and did not again attempt to light the lamp.

About two years since a new day coach which was being built at Pullman, Ill., for the Union Pacific Ry., equipped with carbureters was reported to be destroyed by fire caused by gasoline, but just how we have not been able to learn, if, indeed, the precise cause is known. In regard to this incident, and their experience generally with carbureters. Mr. J. H. McCONNELL, Supt. M. P. and Mach., U. P. Ry., writes us under date of Jan. 19, 1892:

We have some 40 cars equipped with carbureters. As to the matter you asked about—car being destroyed by fire at the Pullman works from use of carbureters—am unable to give you any information, as we have no record of it here. Inexperienced persons handling the sorbed liquid and prevent that free circulation which in a liquid forbids part of it from boiling until all is heated to the boiling point. Part of the gasoline, therefore, may be heated above the boiling point and thus may be generating steam while the rest of it is comparatively cool.

As a homely illustration; conceive a wet sponge held against a hot stove pipe. The interior part will give off steam and rapidly dry while the exterior is still cool and can be held in the hand.* To make the illustration more perfect, conceive an annular sheet iron reservoir packed with sponge saturated with water to be built around a stove pipe; conceive also that there are two small openings in the top of this reservoir; one near the stove pipe, and the other near the outer part of the disk. If the stove pipe be hot enough to make steam at all, will steam begin to come out of the inner opening almost at once, or will it wait until the entire mass of sponge and water within has been heated to the boiling point? We conceive that it will begin to come out at once, and continue indefinitely to come out, chiefly through the inner opening; and this all the sooner if the interior mass be cut up by a spiral partition.

It is true that the core of a carbureter is by no means a stove pipe; but it is separated only by an inch or so of non-conducting air through which radiant heat will readily pass from a pipe which is nearly as hot as an ordinary stove pipe; and then, gasoline is not water. We therefore conceive that this unequal temperature of different parts of the interior is precisely what takes place during the greater portion of the time when carbureters are burning, in any form of the plant; and this conclusion is not greatly affected by whether a part or all of the air supply works its way to the burner through the wicking or takes the short cut above the carbureter through the by-pass.

---

* The fact that 3 lbs. pressure exists in a carbureter makes no difference, except to slightly raise the boiling point, since the same pressure exists inside and out, less a trifling correction to be noted shortly.

For reasons given in detail on page 86 *et seq.*, however, we have grave doubts whether in ordinary practice much air ever works its way through 42½ ft. of spiral passage filled with wicking instead of taking the short cut through the by-pass. The standard by-pass is (or was) the same for all forms of the plant. It will, by experiment, pass about 5.87 cu. ft. per hour under ¼ oz. (0.43 in. of water) pressure, and half that quantity, or some 2.93 cu. ft. under one-fourth of that pressure, or 1-16 oz., which is practically no pressure at all. The usual air consumption, in plants which use most air, is 2 to 3 cu. ft. of air per hour. It may be that a pressure of 1-16 oz. will force a sensible quantity of air through the spiral passages, but we doubt it.*

---

* There is an easy way to test this conclusion, by attaching a pressure gage to the gas pipe between the carbureter and needle-valve. If it indicates more than ¼ to ½ oz. less pressure than exists in the deck pipe, then the by-pass will pass much less air than our experimental tests indicated, and perhaps so little that a certain percentage of air (which may be large or small), is going through the wicking. Whether air thus passes or not, however, does not affect our main conclusions, except that the exit of gasoline vapor from the "air inlet" will be opposed by a pressure equal to some fraction of the difference observed.

These several conditions seem to point to the following conclusions:

A. A very slight difference in the amount of heat present, with hardly any difference in the amount of heat absorbed or radiated, may change the plant from one which charges air with cool gasoline vapor to one which mixes gasoline steam with a varying supply of air, or vice versa.

B. In either case this does or may take place to a considerable extent in the pipes outside of the carbureter, and it is not functionally necessary that any air should pass through the carbureter passages, to make gas.

C. In either case, but especially when any part of any of the carbureters is heated above 110-15°, a rupture of the deck pipes, carbureter connections, carbureters, or interior gas pipes between the carbureters and needle valves is likely to let out an inflammable or explosive gas, and not air only; which gas will continue to come out with some freedom until the temperature of every part of all the carbureters has fallen below 110°, and thereafter more slowly.

D. In either case, but especially when the carbureters and interior of the car are quite warm and the exterior air is cold, after the lamps are extinguished for the night there will be a generation of vapor which will tend to condense in the deck pipes and remain there until the lamps are again lighted. If the deck pipes were entirely filled by this condensed gasoline, as may happen at times, there would be nearly two-thirds of a gallon of gasoline contained therein (enough to supply one lamp for some 17 hours), which would escape as liquid or vapor in case of rupture.

E. If there be any leakage of air about a carbureter, it is essential to safety that if one lamp on a car be lighted all should be lighted; if one lamp be extinguished (for any considerable time) all should be extinguished. Otherwise, the entire interior of all the carbureters on a car and their connecting deck pipes being a single closed chamber, and there being a slow escaping current through the leak, gasoline will tend to distill over from the lighted carbureters and to condense in the unlighted and hence cool, leaky carbureter, which may then become overcharged with liquid gasoline.*

We should be reluctant to express these conclusions about a problem which involves so many complex elements as the precise functional action of this plant, if their correctness did not admit of simple proof or disproof, by a variety of tests, all of which can be made without special apparatus, or much loss of time, or sensible injury to the plant on any car. The tests of this nature which now occur to us, and which are applicable to all forms of the plant alike, are the following:

1. Tap a common gas burner into the deck pipe near a carbureter. Light all the lamps and let the surrounding air be moderately warm. If the accepted theory of the plant be correct, nothing should issue from this burner at any time except air, with

---

* The most probable explanation of the Georgia Central instance of imperfect action of the plant, as above given, seems to us to be that it was an instance of this distilling effect.

perhaps a smell of gasoline. If our theory of the plant be correct, an inflammable gas will issue after the parts are once well warmed up, which will continue to burn indefinitely. If so—

2. Tap in more gas burners in various parts of the deck pipe until it is found that they will not all continue to burn after the parts are well warmed up. If our theory of the plant be correct, the number will be very considerable under favorable conditions. Also—

3. After one or more of these exterior burners are lighted and the carbureters are well warmed up, extinguish all the interior lamps and note how long it is before the exterior burners will go out. If our theory of the plant be correct, it will be a very considerable time under favorable conditions; but with the exterior air colder than 75° to 80°, it will not be long.

4. On a cold day, after burning all the lamps at full height four or five hours in a warm car, stand the car on a slight grade and observe through a cock tapped into the lower end of the deck pipe whether any liquid gasoline can be drawn out. If our theory of the plant be correct some liquid should begin to issue soon after extinguishing the lamps.

5. Without lighting the lamps, expose the exterior of the carbureters to a temperature equal to that which may be derived from a summer sun, with 90° interior temperature. If our theory of the plant be correct, deck gas burners under these conditions can be lighted and will continue to burn.

These experiments may be varied and extended in many ways. They will indicate, should they correspond in result with our conclusions, that rupture of any of the pipes or connections at any point during much of the time when the car is in service, either by day or by night, will not let out air only, but will let out a considerable volume of inflammable liquid or gas, which sinks in air and tends to adhere to clothing or collect in pools, and if any part of it reaches fire anywhere becomes highly dangerous.

The same result will follow, "a fortiori," from any cause which should rip open a carbureter bodily, exposing its wicking freely to the air. That this is extremely difficult to do and that the carbureter is extremely tough and difficult to rupture was shown by experiments detailed at length in our issue of May 16, 1891. These tests have been accepted by many presumably competent authorities, as conclusive proof that under no conditions is a carbureter likely to be torn open in a wreck. We cannot quite agree with them. We agree that these tests showed that it was far more difficult than one would expect to tear open a carbureter injuriously in a wreck, and that it is only in very severe accidents that it is likely to happen. But we do not consider that the test conditions were as severe as they might be made, or as may occur in a passenger collision, and in rare cases we believe it will be found that the carbureter will be so sheared or torn as to expose much wicking to the air—a fact which would be of little moment (because of its rarity) except that when it does happen, if it ever does, will be just when most lives are exposed to the danger of a painful death.

Other dangers of accidents from lamps in service, however, such as "explosions" and the like, we believe are, practically speaking, wholly absent from the plant, contrary to our impressions on beginning this investigation. But besides accidents from lamps in service there are a number of other possible sources of accident which we merely enumerate, and leave everyone to estimate for himself, since the estimate cannot possibly be made precise. The most considerable of these is perhaps—

1. The possibility of inexpert tampering with the details of construction or operation, as by using a lighter gasoline,* turning more heat around the carbureters,† varying the construction of the carbureters, modifying the rules for charging,‡ etc. It is evident that such changes may seriously modify the functional action of the plant, and perhaps injuriously.

2. Gasoline will naturally be kept in stock at a good many points, and in as small quantities as possible, to avoid the risk of fire. It will therefore tend to

---

* This has already occurred; a lighter gasoline boiling at 91° being supplied at many points.

† This also has already occurred, and in a way which many strong friends of the plant regarded as highly injurious. After the original experiments on the Pennsylvania R. R. had been completed, and standard plans for that road adopted, the manufacturing company proceeded to make some considerable changes in the functional action of the plant, which have been fully explained in these articles, by the apparently simple change of adding a damper which threw much more heat around the carbureters. It developed in the course of this investigation that a considerable number of these modified lamps had been placed upon the cars of the Pennsylvania R. R. in the ordinary course of business, without the knowledge or consent of the responsible officers, who thereupon ordered them removed.

‡ Both the construction of and the rules for charging the carbureters have been considerably modified since the first introduction of the plant.

be transported on a good many different trains, and quite possibly at times in passenger trains, in response to telegrams for a supply to some officials' car, or to meet any other unexpected emergency.

3. The dangers of fire and explosion from free gasoline being quite outside of the ordinary experience of ordinary trainmen, it will be impossible to make a large staff appreciate duly with what care it should be handled, especially after a long period of immunity.

4. The stock being naturally kept in a small detached building, at a point convenient for charging, a leak in any one of 80 or more 2-gallon charging cans may generate a gas which any flame may ignite and cause a sudden and fierce fire in the middle of a large yard. This is especially possible if the building be a mere sheet iron shell such as is largely used and recommended.

5. Carelessness in charging, especially with lanterns or locomotives near, may cause a fire.

6. Leaks in the plant on the car at any point may have serious consequences.

These various facts and possibilities lead us to feel grave doubts as to the propriety of using gasoline as an illuminant for cars, even in that safest of all devices ever designed for burning it, the Frost carbureter plant. This seems especially so because it does not appear from any facts known to us and recorded in these articles that the carbureter furnishes either a better or a cheaper light than can be obtained from 300° oil or from compressed oil gas. But in closing this long series of articles we desire to say again, as we have said before, that a case can be made out in favor of the safety of that system for general use so strong that, if not strong enough to withstand all tests of a rigid investigation, is at least so strong as to make it pardonable for any man to have believed it invincible and acted accordingly. Many railway officials of the highest character and standing, having a responsibility on their shoulders which we have not, have so acted and so concluded. Should the worst railway holocaust on record occur to-morrow and be directly traced to the use of gasoline for car lighting, we shall have no word of reproach to say to them nor of them. Should such an accident occur two or three years from now, however, unless we have obtained more light in the meantime than we now have as to some of the difficulties suggested in this article, it may be a different matter.

APPENDIX.

Car Lighting by Storage Batteries: Jura & Simplon Railway.

An article in the "Railway Engineer," of London, England, by W. R. Weyermann, Locomotive and Car Superintendent of the Jura & Simplon Railway, of Switzerland, gives an interesting account of the experiments made on that road with electric lighting for cars. The experiments were commenced in 1889, and as through trains in Switzerland are made up of cars belonging to different railways, and have to be divided after a few hours' run, for the cars to proceed along the different lines, the only available system is one in which storage batteries are used, each car carrying its own batteries. At the end of 1891 the company had 18 first and second-class cars, 60 third-class cars and 12 baggage cars. or 90 cars in all, fitted with the electric light, and 120 new cars are also to be fitted with it.

The secondary batteries weigh 242 lbs. each, including the wooden casing, and are easily carried by two men. Each battery consists of three ebonite troughs, fastened tightly in a wooden case, and each trough contains three cells, with positive and negative plates dipped in a solution of one part sulphuric acid to ten parts water. The nine cells are joined in series, giving a total pressure of 18 volts.

The weight of the electrodes is 158 lbs. The practical capacity of the battery is 125 ampere-hours, the maximum discharge current being 15 to 18 amperes. The incandescent lamps require three watts of electric energy per candle power, to raise them to their normal brilliancy, which with a tension of 18 volts, gives a current of 1-6 ampere per c. p. The battery has a capacity of about 750 c. p. hours, with a maximum of 100 c. p. The lamps are of 10 c. p. for the compartments, and 5 c. p. for the lavatories and end platforms, the cars having through communication. The first-class cars have lights of 70 c. p., the third-class, 40 c. p., and the baggage cars 30 c. p., and one battery will, therefore, light a first-class car for 10 1-2 hours, and a third-class car for 18 1-2 hours. All new cars will have room for two batteries, as by some of the new traffic arrangements for through cars over connecting lines, one battery will not be sufficient to supply the light until the car gets back to the charging station. The battery is carried under the body of the car, in a box 29 1-2x19 1-4 ins. and 15 3-8 ins. deep. When the battery is pushed into the box the two poles come in contact with two strips of brass on the bottom of the box, from which insulated copper wires run to one end of the car. The main wires run from end to end of the car, and are covered by the ceiling cornices, which protect them and give security against short circuits. Two wires of small section connect the two mains to the lamps. In second and third-class cars, one of the main wires is provided with a switch at the end of the car by which the current can be turned on or off by a special key carried by the conductor. First-class cars, which often have empty compartments, have a similar switch to each compartment.

The incandescent lamps have brass sockets and extra strong fixings for the platinum wires, and are specially made for a pressure of 18 volts. They are manufactured by Siemens & Halske, of Berlin. To prevent the lampholder contacts from being damaged by short circuit, one of the wires to the lamp is provided with a thin strip of tin foil, which will fuse in case the current should exceed a certain strength, and the main wire from the positive pole of the battery is provided with a strip of tin foil for the same purpose. The lamps are placed under the ventilators, the current of air cooling the lamp and reducing its deterioration. As an experiment for lowering the lights at night, without the use of complicated devices, the single lamp of 10 c. p. in each compartment was replaced by two lamps of 5 c. p. in the same globe, and the separate switch was so arranged that the lamps could be joined parallel or in series, burning with full or half power respectively. The same effect could have been attained with one lamp by using additional resistance, but then the loss of electric energy would have been the same at full and reduced power, while the joining of two lamps in series reduces the working current. The first cost and working expenses, however, and the extra lamps, holders and switches, would have been out of proportion to the advantages gained and the arrangement was soon abandoned.

In order to keep the storage batteries in good working order it is essential to limit the discharge, for when this exceeds a certain limit the electrodes begin to lose a part of their accumulating power and their efficiency is reduced. For the second and third-class cars, all the lights of which are controlled by one switch, the number of hours was determined during which the battery could give a normal current without exceeding the limit of 750 c. p. hours. For registering the number of hours a clockwork device is used, which is placed under the car, near the battery box, in a cast iron box with a glass face, the dial being graduated for 30 hours, and the starting hour worked by a red arrow. This device is connected with the switch, so as to register the time the current has been flowing. The employees who change the batteries at certain stations can see at once whether a new battery is needed, and whenever a battery is put in the clockwork is wound up and the arrow set to the starting point. The maintenance of batteries is contracted for by the Marly Electric Storage Battery Co. at $5 per battery per annum. The spent batteries removed from the cars are sent in a special car to the railway company's works at Fribourg, where they are recharged without being unloaded. The battery cars carry 60 batteries in 12 sets of five each, joined in series. The charging pressure for each set of five batteries is 109 to 110 volts, and the batteries are charged when the pressure of each set reaches 105 to 108 volts.

INDEX.

Page.

Accidents:
  Brice, Private Car of Calvin S................. 269
  Chemin de Fer de l'Est......................... 251
  Central Railroad of Georgia............54, 266, 284
  Central Railroad of New Jersey............247, 249
  Charging cars with gas..............117, 247, 265
  Chicago & Alton R. R........................ 251
  Chicago & West Michigan Ry................ 271
  Cincinnati, Hamilton & Dayton R. R.......... 255
  Foster gas plant..........................3, 246
  Frost carbureter system..................54, 265
  Gasoline...................................... 273
  Grand Central Station...................247, 263
  Great Northern Ry............................ 273
  Great Western Ry. of Canada................ 254
  Harrisburg, Pa.............................. 247
  Kerosene. (See Oil lamps.)
  Mail service, Railway....................234, 258
  Mott Haven, N. Y............................ 246
  New York Central (dynamite explosion)....... 241
  Norfolk & Western.........................49, 250
  Oil lamps......................138, 234, 254, 263
  Pennsylvania R. R., Thompsontown.......... 250
  Pintsch gas system.......................... 246
  Railway mail service....................234, 258
  Rothsay, Minn., Great Northern Ry........... 273
  St. Louis, Iron Mountain & Southern Ry...... 255
  St. Louis lady................................ 274
  Savannah, Florida & Western Ry.............. 254
  Seacombe, Hoylake & Deeside Ry. (England).. 248
  Tank, Explosion of oxygen................... 251
  Thaxton's, Va., Norfolk & Western Ry......49, 265
  Thompsontown, Pa., P. R. R................. 250
  Wabash R. R................................ 255
  Wannsee, Germany........................... 250
Acme lamp................................151, 157
Adams & Westlake.........................152, 157
Ainslie (Gen. Manager Wis. Central)..........264, 272
Air, Percentage of gasoline vapor absorbed by..... 10
American Lighting Co......................... 3

Page.
American Railway Association, Investigation of car lighting by.................................. 261
Arc light.. 211
Argand burner.................................... 147
Ayres, Arthur (Inst. C. E., paper by).............. 100
Baltimore & Ohio R. R., Estimate of cost of different systems of lighting for..............221, 235
  Specifications for oil for...................... 144
Barrett, S. H. (Supt. Telegraph, Conn. River R. R.) 171
Bauer, A. H. (Supt. Elec. Dept., Pullman Co.)..180, 189
Beaume scale..................................... 7
Belgian burner................................... 154
  Candle power of................................ 200
Blodgett, G. W. (Elec. engineer, Bost. & Albany R. R.).. 166
Boiling points of petroleum products.............. 4
Boston & Albany R. R., Electric light on.......... 166
Bowman, John D., Test of Frost carbureters by.. 93
Burlington, Cedar Rapids & Northern Ry., Elec. light on... 167
Canada Atlantic Ry., Elec. light on................ 168
Candles..1, 169
Candle, Standard for photometric tests............ 197
Candle-power of various lights.................200, 207
  Electric lamps................................. 210
  Horizontal and circular........................ 197
Cape Colony Government Rys., Elec. light on.... 178
Calorific power of combustibles.................. 275
Carbons for electric arc lamps.................... 211
Carbureter system. (See Frost carbureter system.)
Car lighting, Report by International Ry. Congress. 132
  American Ry. Assoc. on......................... 261
Carpets, Damage by oil on Pullman cars.......... 60
  Accidents from tripping over................... 240
Cars, Hours lighted per day, average............. 69
  No. of pass. equipment, U. S. and Canada...... 225
Central draft burners, oil lamps.................. 148
Central R. R. of Ga., Accident on.........54, 266, 284
Charging cars with gas...............238, 117, 247, 265
Charging cars, comparative frequency with different systems of lighting.......................... 237
Chesapeake & Ohio Ry., Cost of elec. light on.... 180
Chicago, Milwaukee & St. Paul R. R., Elec. light on 169, 184, 187
Compression of gas, Effect on candle power........ 222
Conn. River R. R., Elec. light on..............171, 186
Cory, C. H. (Supt. Motive Power, C. H. & D. R. R.) 255

Page.

- Cost, of car lighting systems 213
  - Attendance and supplies 233, 236
  - First cost, Comparative 213
  - Frost carbureter system 218
  - Illuminant per car, various systems 232
  - Oil lamps 213
  - Operating 222, 235, 236
  - Total yearly of various systems 235
- Cotton, C. A. (Electrician Safety Elec. Light Co.) .. 163
- Dayton Mfg. Co 152, 156
- Depreciation:
  - Electric lighting systems 183
  - Frost carbureter system 220
  - Oil lamps 214
  - Pintsch gas 218
- Dibdin radial photometer 12
- Distribution of light 206, 208
- Dixon, Robt. M. (Eng. Safety Car Htg. & Ltg. Co.) 110
- Drip cups for oil lamps 151
- Dudley, Dr. Chas. B., (Chemist, P. R. R.) .. 38, 70, 135
- Duplex burner 148
- Dynamite, Danger in handling 240
- Electric lamps, Candle power of 210
- Electric Lighting 160
  - Advantage of 160
  - American practice in combined dynamo and storage battery systems 179
  - Brush storage battery 166
  - Candle power of 210
  - Carbons for arc lamps 211
  - Cars lit in England 177
  - Combined dynamo and storage battery system with cells on every car 170, 187
  - Combined system with cells on one car 170, 185
  - Cost of 180, 191 238
  - Difficulties in 160
  - Direct dynamo system 168
  - Dynamo driven from car axle 171
  - Earliest use on cars 165
  - English experience in 171, 177
  - Incandescent lamps, candle power of 210
  - Julien Electric Co 166
  - Jura & Simplon Ry 280
  - Khotinsky system 168
  - Pennsylvania limited train 179
  - Primary battery systems 162
  - Size of plant for American trains 162
  - Storage battery systems 164

- Electric lighting: Page.
  - Storage batteries, Jura & Simplon Ry.......... 290
  - Systems of.................................. 161
  - Track wire system........................... 164
- Ely, Theo. M., (Supt. Motive Power. P. R. R.).... 236
- Erie R. R., Pintsch gas plant at Jersey City..107, 218
- Faure accumulators.............................. 164
- Foster gas process......................3, 113, 240
- Frost carbureter system, general description.21, 26, 75
  - Action of in service........................ 80
  - Air supply, general practice................37, 83
  - Air supply, P. R. R. practice................... 35
  - Air supply, why not heated in general practice. 41
  - Air supply, All through by-pass............... 67
  - Air supply, Tests of amount of................ 17
  - Air tank....................................27, 68
  - Blowing out of lamp; How prevented.......... 40
  - By-pass, Office of............................ 37
  - Candle Power of; Various lamps.............. 290
  - Carbureter, general description................ 33
    - Capacity of................................ 64
    - Drop tests of......................33, 46, 286
    - Fire test of............................... 44
    - Interior construction of.................... 43
    - New square................................ 63
    - Strength to resist bursting................. 67
    - Weight of.................................. 34
    - Weight of separate parts.................... 68
    - When to fill............................... 32
  - Cars equipped with........................... 24
  - Charging carbureters.......................... 58
  - Charging can................................. 59
  - Charging can storehouse...................... 63
  - Check valve and dust screen.................. 28
  - Distribution of light from.................... 208
  - Equal burning of lamps necessary............ 284
  - Excelsior lamp................................ 77
  - First cost of.................................. 218
  - Functional action of........................75, 281
  - Gasoline, Boiling of in carbureters.........179, 194
  - Gasoline, Consumption of................16, 69, 226
  - Gasoline, Condensation in deck pipe........91, 283
  - Gasoline, Condensation in pipe to burner....... 39
  - Gasoline, Lighter grade of supplied............ 287
  - Gasoline vapor blown off at safety valve....39, 91
  - Heating of carbureter.................40, 79, 279
  - Hours burning between chargings........66, 70, 92
  - Indicators for................................ 80
  - Instructions for use........................68, 287

Frost carbureter system: Page.
  Lamps used with.........................77, 200
  Regulators for.................................. 26
  Rules for operating........................63, 287
  Original form of............................... 23
  Pennsylvania R .R., Practice in. (See Pennsylvania R. R.)
  Safety valves.................................. 30
  Safety of.......................................50, 265
  Smokebell, Changes in........................ 41
  Temperatures in carbureter.............40, 79, 279
  Strength of carbureter..................33, 46, 288
  Time between chargings................66, 70, 92
  Ventilator, Changes in........................ 42
  Wicking in carbureter.....................33, 69
  Wicking, Probable life of..................... 65
Garstang, Wm. (Supt. Motive Power, Ches. & Ohio) 189
Gas, Candle power of............................ 222
  Consumption of per c. p. hour................ 200
  Invention of.................................... 245
  Loss of candle power by compression.......... 222
Gas compressor at Boston gas works.............. 98
Gas jet, Difficult to ignite...................... 251
Gas lighting. (See Pintsch gas system.)
Gas making, by Pintsch system.................. 97
Gasoline, Accidents from......................... 273
  Amount required for lighting all cars........9, 228
  Annual production of........................9, 223
  Consumption of.................................. 227
  Consumption of, per c. p. hour................ 200
  Cost per gallon of............................. 229
  Danger of....................................... 243
  Heating power of............................... 275
  Insurance on buildings lit by.................. 22
  Latent heat of evaporation..................... 276
  Lighting buildings with........................ 21
  Loss of, by evaporation........................ 63
  Methods of purchasing.......................... 63
  91° supplied for 88°........................... 67
  Vapor retained in air.......................... 10
  Vapor heavier than air......................... 274
Gasoline system of car lighting. (See Frost carbureter system.)
Gas works. (See Pintsch gas system.)
Gibbs, Geo. (Mech. Engr. C. M. & St. P. R. R.
  2, 134, 183, 191, 215, 221, 229, 233
Great Northern Ry. England, Elec. light on........ 173
Headlight oil.. 8

Page.
Heap, Major D. P., Tests of oil lamps for U. S. Light House Board........................ 149
Hunter, Gilbert M., (Inst. C. E.), paper by......... 97
Howard, Jas. L., (car lamp manufacturer)......... 152
Hydrocarbon, at Pintsch gas works............... 102
Illuminants.......... 3
Illuminants, Distinction between safe and dangerous 243
Incandescent lamps. (See Electric lighting.)
Intercolonial Ry., Electric light on................ 167
International Ry. Congress, Discussion on elec. light..................................... 181
Insurance rates, Affected by use of gasoline....... 22
Insurance Co., Boston Manufacturers' Mutual..259, 260
Jura & Simplon Ry., Elec. lighting on............. 280
Kerosene, Accidents from............138, 234, 254, 263
Kerosene, Proportions of, in petroleum............ 222
Khotinsky electric lighting system................. 168
King's treatise on coal gas....................... 11
Lamp. (See oil lamps, also under Pintsch gas system and Frost carbureter system.)
Langdon, Wm. (Inst. C. E.), paper by..........174, 190
Leeson disk....................................... 16
Light and heat tender............................ 183
Light, Amount required in a car...............162, 236
Light, Distribution of........................... 208
Lights, Spacing of, in a car...................... 204
Lima oil, Production of.......................... 224
London & Northwestern Ry., Pintsch system on... 129
London & Southwestern Ry., Elec. lighting on...... 178
London, Brighton & South Coast Ry., Elec. light on. 165,172, 185
Mail service, Railway, Accidents in...........234, 258
Marly Electric Storage Battery Co................ 203
McConnell, J. H., (Supt. Motive Power, U. P. Ry.) 264, 270
Methuen screen.................................. 16
Midland Ry. (England), Elec. light on.........178, 190
Mineral sperm oil. (See oil.)
Moehring burner.................................. 149
Naphtha, Increase in production of............... 224
New York, Lake Erie & Western R. R., Pintsch system on.............................107, 218
Norfolk & Western, Thaxton's wreck on.........48, 265
Oil, cloudy.................................143, 146
  Consumption of per c. p. hour.............149, 200
  Cost per gallon of.......................... 229

- Oil: Page.
  - Damages from drip and spilling............66, 233
  - Mineral sperm used for car lighting........... 134
  - Specifications for, B. & O. R. R................ 145
  - Specifications for, P. R. R..................... 138
  - Vegetable, used abroad........................ 132
  - Water white required.......................... 143
- Oil gas. (See Pintsch gas system.)
- Oil gas, Candle power of.......................... 222
- Oil gas, Production of, per gallon oil.............. 225
- Oil lamps.. 132
  - Acme...................................151, 157
  - Belgian.................................154, 200
  - Burners, for................................. 147
  - Candle power of.............................. 200
  - Cost of equipping cars with.................... 213
  - Cost of operating............................. 232
  - Depreciation of.............................. 214
  - Distribution of light from...................... 209
  - Exposed situations........................... 155
  - Filling of.................................... 238
  - French practice in........................... 133
  - Explosions of...........................138, 253
  - Household use of.........................146, 263
  - Necessary qualities for car lighting............ 151
  - Safety of...............................138, 253
  - Use with electric lights....................... 183
  - Variations in candle power.................... 207
  - Westlake.................................... 155
- Olhausen, J. H., (Supt. C. R. R. of N. J.)......246, 248
- Operating expenses of car lighting systems. (See cost of operating.)
- Paraffine series.................................. 4
- Paris, Lyons & Mediterranean Ry., Elec. light on.. 165
- Penniman, W. B. D. (Chemist, B. & O. R. R.) 2, 93, 194, 228
- Pennsylvania limited, Elec. light on............... 188
- Pennsylvania R. R., Elec. light on............165, 179
  - Frost carbureter system on 23, 30, 32, 35, 38, 40, 71, 73, 77, 85, 196, 272, 287
- Petroleum, Annual production of.................. 8
  - Distillation of..........................4, 135, 222
  - Exportation of (statistics)...................... 9
  - Price of, average 1881-91...................... 8
- Petroleum products............................ 4
  - Price of..................................... 9
  - Yearly output of.............................. 9